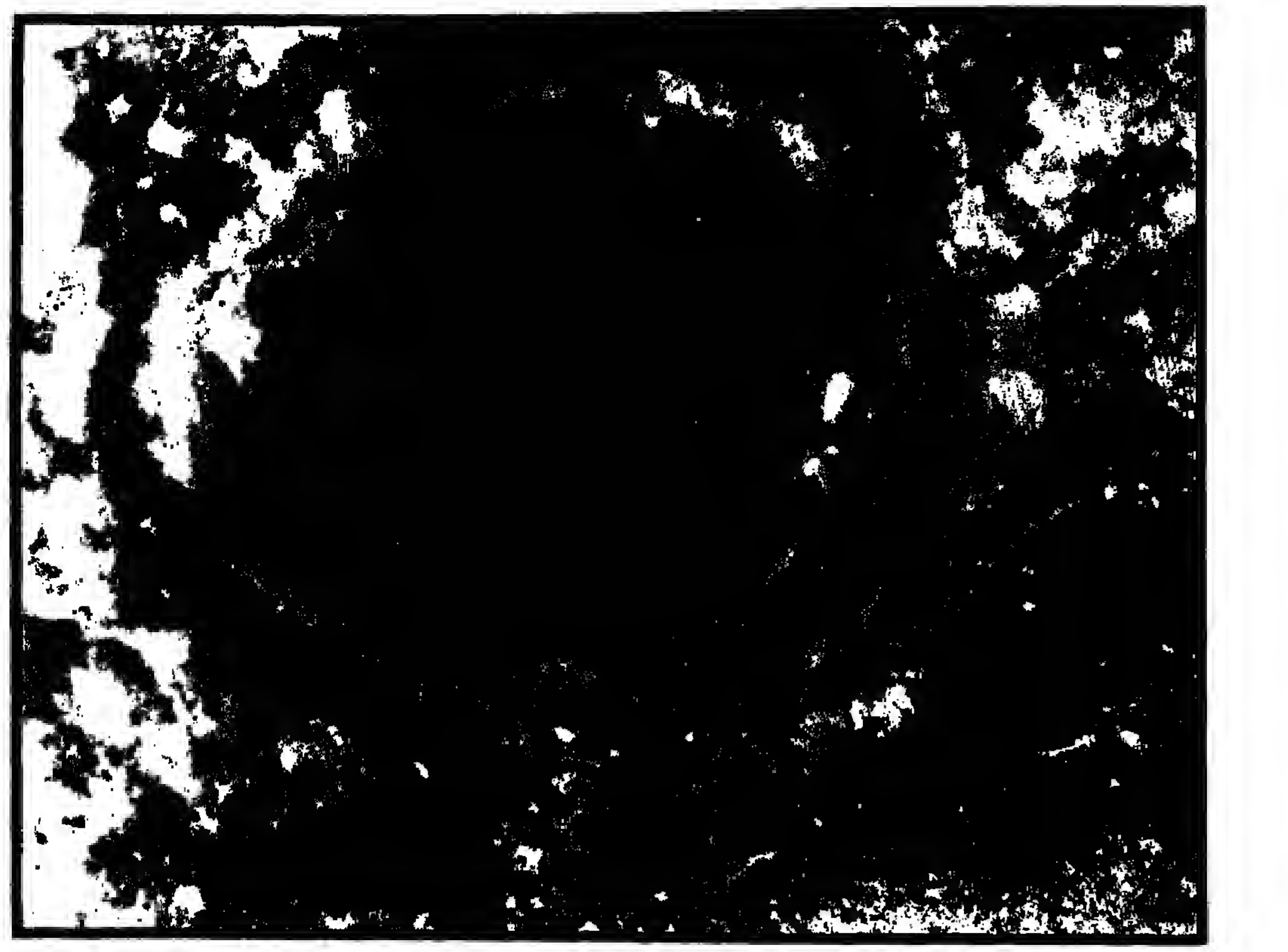

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION VOL. 62, NO. 7, PAGES 65-72 FEBRUARY 17, 1981

Oceanography

4720 Distributions and water masses
HYDROGRAPHIC OBSERVATIONS OF NORTHERN CALIFORNIA DURING MAY 1977
H. Paul Freitag (NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, Washington 98115) and D. Halpern
A hydrographic survey of 286 CTD stations was made in May 1977 in the region between 37°N (i.e., near San Francisco) and 43°N (i.e., Cape Blanco in southern Oregon). Coastal upwelling was most intense south of Cape Mendocino. At 300 m an intense temperature and salinity frontal zone occurred between 38°N and 39°N. The dynamic height topographies 0/900 db and 300/900 db contained regions of highs and lows with length scales of 100-150 km. North of Cape Mendocino the warm saline water identified as the poleward California Undercurrent was not observed and the transport integrated above 500 db was southward. (California Current and Undercurrent, eddies, fronts).
J. Geophys. Res., Green, Paper 1C0007

Circulation in the Coastal Ocean, Part 3

G. T. Csanady

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This paper is the last of three parts. The previous two parts were published in Eos January 13 and February 3.

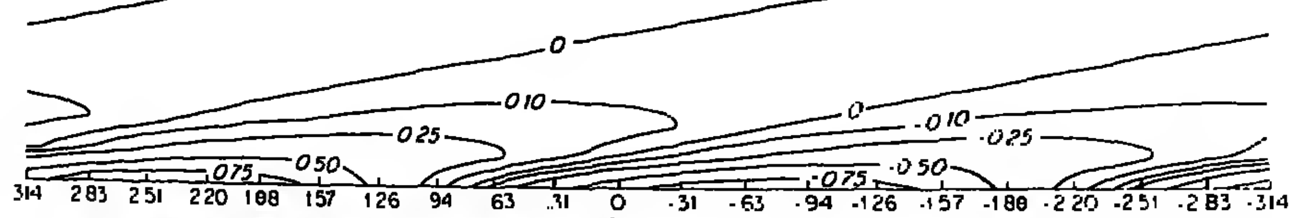

Fig. 1. Sea-level distribution over idealized shelf with sloping bottom due to sinusoidally varying longshore wind. Stress is maximum positive (toward positive y) at center, $ky = 0$, maximum negative at $ky = \pm\pi$. Longshore pressure gradient largely opposes the wind stress, but the pressure field decays with a typical offshore scale of 10-30 km. (From Csanady [1978].)

Shelf Circulation as a Boundary Layer Problem

The simple models of shelf circulation components discussed so far were based on the coastal constraint assumption and longshore uniformity. This is clearly restrictive: how far from shore the coastal constraint is valid is itself one of the important questions in shelf dynamics. A longshore sea-level gradient constant in space and time is evidently not a realistic assumption over larger pieces of the coastline. The focus of much recent work on shelf dynamics has been on determining the mechanism that allows longshore sea-level gradients to exist along open shelves, and the distribution of such gradients. The excitement of finding answers to such questions is still fresh for those of us involved in the exercise.

In a simple approach, it is reasonable to neglect the small-scale variations of shelf topography or of forcing in the longshore direction and to focus on such physical influences as major changes in coastline orientation or wind stress variations on the scale of weather systems. It is then still realistic to regard the coastal zone of interest as a narrow boundary region of a larger-scale circulation pattern. An appropriately simplified equation governing coastal sea levels now takes on the form of the heat conduction (or diffusion) equation, according to which any sea-level perturbation spreads out in the offshore direction, proceeding in a cyclonic direction alongshore. The theoretical model thus predicts the formation of an inner-shelf boundary layer which thickens in one specific longshore direction only, and that is in the direction of long-wave propagation.

The rate at which the frictional coastal boundary layer grows (related to the effective horizontal diffusivity for sea-level perturbations) is proportional to the bottom resistance coefficient. In typical cases, a disturbance comes to occupy the entire shelf width (order 100 km) in a longshore distance of order 2000 km, which is comparable to the scale of weather systems or to continental dimensions. Much closer to the source of the disturbance (which may be simply a change of coast orientation), its effects remain confined to an inner-shelf boundary layer.

The boundary layer model allows considerable insight into the mechanism of longshore pressure gradient generation by such local influences on a shelf region as longshore or cross-shore wind stress distributed in an arbitrary way. Figures 1 and 2 illustrate the effect of a sinusoidally varying longshore wind on a long, straight shelf of constant slope, with the deep ocean supposed 'inert.' The first of these illustrations shows that a varying longshore wind sets up a coastally trapped steady pressure field akin to a topographic wave. If the longshore wavelength of the forcing is 1000 km, a typical value of the bottom resistance coefficient results in a trapping width of 50 km, i.e., trapping in a moderately narrow nearshore band. The dynamical role of the peculiar pressure field is elucidated somewhat by the transport streamline pattern of Figure 2. This figure shows the transition between the region where the coastal constraint is valid, and the longshore force balance is between wind stress, bottom stress, and longshore pressure gradient, and an 'outer-shelf' region where the total transport is only what flows onshore or offshore in a surface Ekman layer, so that most of the water column is quiescent.

Figure 1 shows that a specific distribution of surface levels is required to bring about the required balance of forces and that this is associated with a peculiar distribution of interior velocities over the inner shelf. Certainly physical intuition would not lead one to expect such a distribution. Of particular practical importance is the model prediction that the cross-shore transport can be of significant magnitude as close to shore as 10 km, depending on topography, forcing, etc. The inner-shelf longshore current transports varying amounts of fluid, accepting the inflow from a surface Ekman layer further offshore, where the longshore wind stress drives it shoreward, and supplying the outflow, where the longshore stress is oppositely directed.

In a qualitative application of this model to realistic coastline geometry, one may think of longshore variations in forcing as being due to changes of coastline orientation. The calculated results suggest that the flow accommodates itself to such changes within an inner-shelf boundary layer, with the outer shelf not being affected. The open circulation cells associated with the flow adjustment should have considerable practical importance as a mass exchange mechanism.

More complex wind fields lead to more complex solutions. Whatever the details, however, the parabolic nature of the governing equation and the effective horizontal diffusivity related to bottom friction govern the character of the solutions. Different driving forces may be thought of as driving different components of shelf circulation that are simply additive.

The effects of variable cross-shore wind stress show some interesting effects not revealed by the previous illustrations (Figures 3 and 4). The sea-level distribution is characterized by something like wind setup, showing a drop in levels near the maximum offshore wind and a rise near the onshore wind maximum. However, surface-level gradients are only significant within a coastally trapped band, which should have a typical width in practice of 10-30 km. Outside this band, the cross-shore wind stress is balanced by Ekman drift, as in the deep ocean. However, the Ekman drift in this case is not constant but rather has convergent and divergent regions. Over a sloping shelf, this leads to massive onshore flow (outside the region where setup is important) where the surface layer is divergent, offshore flow where it is convergent.

A potentially important forcing effect on the shelf circulation is the pressure field impressed by the deep ocean. In the boundary layer model, this appears as a boundary condition at the outer edge. A longshore pressure gradient impressed at the edge of the shelf affects the entire shelf much as the free-stream pressure gradient affects a laboratory boundary layer, on the reasonable supposition that the longshore scale of such a gradient is comparable to oceanic dimensions. Such an 'impressed' pressure gradient is thus more or less constant with distance from shore and leads to effects as discussed earlier in connection with the parallel flow shelf circulation model (Figure 6, part 2; *Eos*, February 3).

The effects of variable freshwater inflow are also easily treated with the aid of the boundary layer model. Freshwater inflow is concentrated in major rivers, and even if each of these becomes effectively distributed over a few hundred miles of coastline, there are important variations in the rate of inflow between, say, the northerly and southerly part of continents. Such variations are responsible for longshore density and, hence, pressure gradients, which may be significant producers of shelf circulation. For example, if the density changes by 1 part in 1000 over a longshore distance of 1000 km, over a water column 100 m deep, a longshore sea-level slope of 10^{-7} results (1 cm in 100 km), which is of the same order as longshore gradients that are due to other causes. A slope of this magnitude should drive massive longshore flow, according to the boundary layer model.

Over the Mid-Atlantic Bight, the observational evidence suggests that no significant trapped cells affect the mean flow beyond the 30-m isobath or so. The key driving force, the longshore pressure gradient, is then very likely a deepwater effect, impressed upon the shelf by offshore oceanic gyres. At the edge of the shelf this longshore gradient is certainly as large as it is closer to shore.

The magnitude of the longshore pressure gradient is not constant in time, however, but is subject to clear seasonal—and perhaps longer-term—variation. An interesting aside is that at the time of the *Argo Merchant* oil spill off Nantucket Island (December 1976), the usual southwestward driving longshore pressure gradient was fortuitously absent, and the water column was moving eastward under strong northwest winds, taking the oil spill eastward and out to sea.

One factor contributing to longshore sea-level gradient, at least in the northern portion of the Mid-Atlantic Bight, appears to be freshwater influx further north, notably in the Gulf of Maine and the Gulf of St. Lawrence. According to the boundary layer model, longshore variations of freshwater influx over such a long range (order 1000 km) affect more or less the entire width of the shelf, which would make their effects difficult to distinguish from deepwater gyre effects. The magnitude of the longshore pressure gradient that is due to observed density variations may be estimated to be 1 cm in 100 km (10^{-7}) during the spring runoff period only, and a much lower slope at other times of the year. This effect may partly explain the seasonal variation of the longshore gradient.

Over the inner shelf, evidence for the theory that trapped cells affect the long-term mean circulation pattern comes from nearshore studies in different locations. These show different magnitudes of the longshore pressure gradient. Near the 'apex' of New York Bight, such local variations are particularly clear. The details of these trapped cells have not been elucidated so far, at least not in connection with a long-term mean circulation pattern. On the other hand, there is clear evidence which shows that trapped pressure fields accompany storms.

Storm Currents over Atlantic-Type Shelves

From an economical point of view, the most important problem in applied oceanography is the prediction of storm surges, which from time to time cause tremendous damage along coastlines adjacent to broad continental shelves such as the North Sea, the U.S. Gulf Coast, and the East Coast. Consequently, numerical models are well developed for the prediction of coastal sea levels associated with hurricanes and extratropical storms. These models have been calibrated empirically and today constitute a useful practical tool. They do not, however, give a particularly realistic description of storm-driven currents, at least not without considerable further

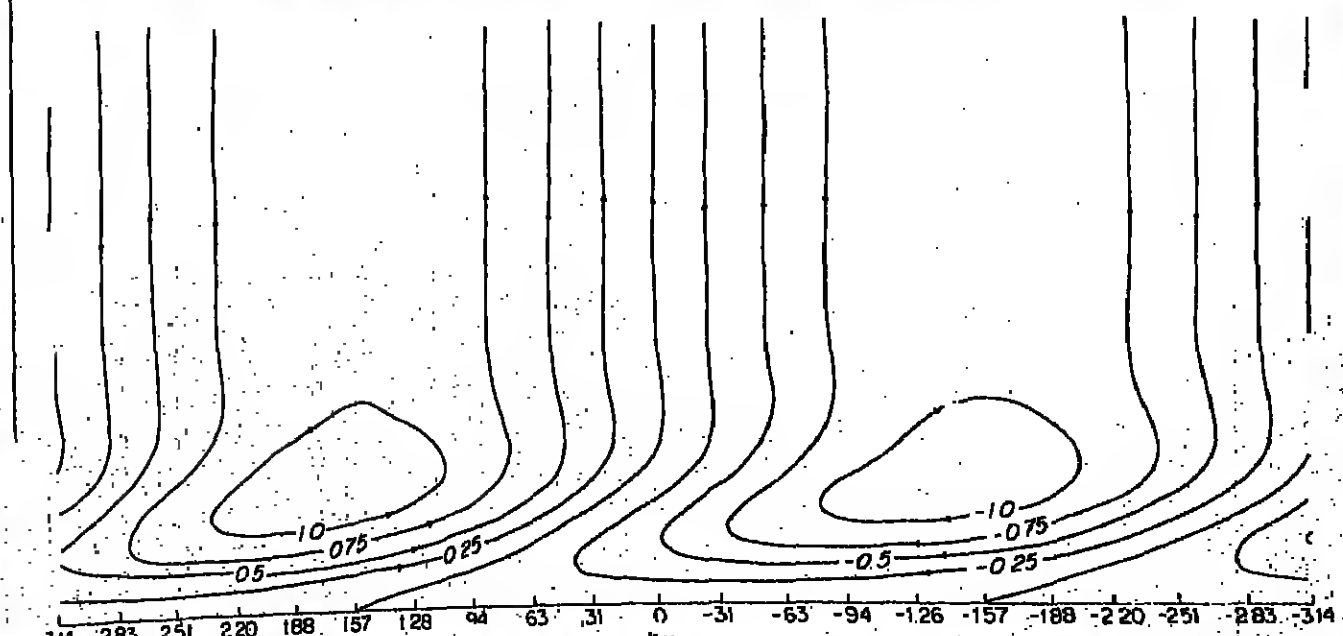

Fig. 2. Transport-streamline pattern corresponding to pressure field shown in Figure 1. Transport is in phase with the wind at the shore, but far from shore it becomes cross-shore Ekman transport associated with longshore wind stress.

EOS

TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

The Weekly Newspaper of Geophysics

Eos, Transactions, American Geophysical Union (ISSN 0096-3941) is published weekly by the American Geophysical Union from 2000 Florida Avenue, N.W., Washington, D. C. 20009. Subscription available on request. This issue $5.00. Second-class postage paid at Washington, D. C., and at additional mailing offices.

Cover. This photo presents an interesting meteorological question. These cloud patterns, imaged from space by a Defense Meteorological Satellite, were produced by a mature mid-latitude cyclone with a well-developed typhoon located near the southern end of the occluded front. The thermal infrared band image, in which the brightest areas are higher (colder) cloud tops and the gray areas are lower clouds, was taken over the eastern Pacific Ocean, about 2500 km off the California coast, in 1975. This image is oriented north (top)-south (bottom), with the nearest northwest landmass being the Aleutian Islands. The southernmost portion of the image is near the equator. (Photograph and information courtesy of James Barnes and Alan Buffey, Environmental Research & Technology, Inc., Concord, Mass.)

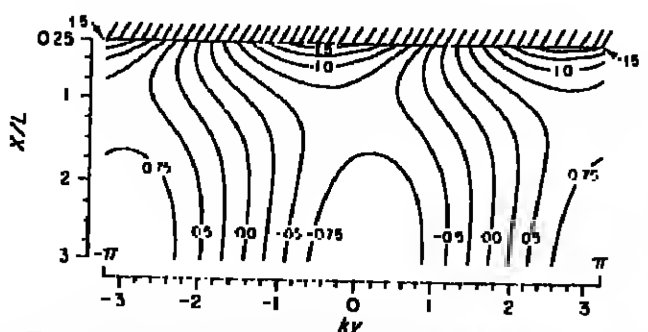

Fig. 3. Sea-level distribution over idealized sloping shelf due to sinusoidally variable cross-shore wind stress. Wind stress is maximum offshore at $ky = 0$, maximum onshore at $ky = \pm\pi$. Setup opposes the wind over the inner shelf, while over outer shelf, sea-level distribution is in geostrophic balance with subsurface flow (see next illustration). (From *Csanady* [1980].)

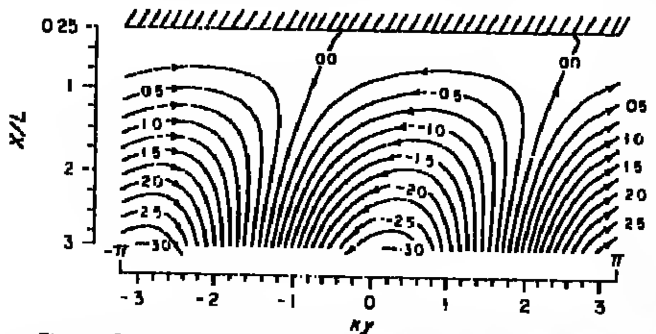

Fig. 4. Transport streamlines corresponding to pressure field in Figure 3. Over outer shelf there is massive onshore flow in region where wind-stress curl is cyclonic ($ky \sim \pi/2$), offshore flow where anticyclonic ($ky \sim -\pi/2$).

development and calibration. In any event, the predictions of the models are almost as complex as the observational evidence, and it is desirable to understand the contribution of storms to the circulation problem in terms of simpler concepts.

Strong winds acting over shallow water rapidly establish frictional equilibrium flow, so that this aspect of the circulation problem is best approached by way of steady state models. The classical models of hurricane surge are of this kind [*Freeman et al.*, 1957; *Bretschneider*, 1966]. Although wave-like 'resurgences' are sometimes important, the bulk of the coastal sea level rise attributable to storms can be explained as a steady state, coastally trapped pressure field. Associated with this pressure field are intense longshore currents which are generated by storms, presumably giving rise to large particle displacements. *Boicourt and Hacker* [1976] point out, for example, that most of the mean southwestward drift off Chesapeake Bay in the Mid-Atlantic Bight is generated by a few nor'easterlies, as vividly illustrated in their paper through the use of progressive vector diagrams of observed currents.

In a steady state model, coastal sea level rise is due to two effects: setup in response to onshore wind and geostrophic adjustment to balance the Coriolis force of longshore currents. From the point of view of the circulation problem, coastal sea levels are incidental, but of course longshore gradients of sea level that form part of a trapped pressure field under a storm affect the intensity of longshore currents. Of great practical importance for mass exchange are the cross-shore motions in the open circulation cells associated with trapped pressure fields. The simple boundary layer models discussed above have shown that the longshore scale ('wavelength') of the forcing by wind is of key importance in determining the circulation pattern. Storms of small spatial scale may create a particularly intense circulation cell on the continental shelf.

Extratropical storms have typical scales of 1000 km and more. Hurricanes are 3–10 times smaller in diameter, but their maximum winds are much higher. Maximum wind stress in a hurricane reaches values of 30 Pa and more.

Clear evidence for a trapped pressure field associated with hurricanes has already been presented by *Redfield and Miller* [1957] (see Figure 5 here). The maximum longshore sea-level gradient shown in this illustration is about 6×10^{-6}, which, in water 50 m deep, would alone drive a longshore current with a velocity of about 1.5 m/s. Moreover, this gradient drives the water in the same direction as the longshore stress ahead of the eye of the hurricane just prior to landfall and so increases the maximum longshore current above what the wind stress alone would produce.

Intuitively, the sea-level distribution shown in Figure 5 is not difficult to understand as an effect of the cross-shore component of the wind that causes a setup to one side of the eye, a set-down to the other side. A similar effect is revealed by the boundary-layer shelf model acted upon by variable cross-shore wind, the sea-level distribution for which is shown in Figure 3. Figure 4 shows the corresponding streamline pattern. The equivalent of the eye of a storm is located in both figures to the right of the center, where the cyclonic curl of the wind stress causes substantial onshore transport. The coastally trapped pressure field is instrumental in deflecting the onshore flow in a longshore direction and causes strong longshore currents without any longshore wind. In an actual storm, of course, the important effects of longshore winds are superimposed on this pattern.

The longshore component of the wind in a storm generates a pressure field that generally opposes the wind stress, and hence the longshore current close to the coast (cf. Figure 1). Summing the effects of cross-shore and longshore winds causes partial cancellation of the longshore gradient in the case when the storm center is located offshore. With the storm center over land, the pressure gradients add up, both opposing the direct driving force of the wind. The relative strength of the longshore gradients produced depends on the spatial extent of the storm. For a hurricane (small diameter), the cross-shore wind effect dominates, as empirical data show in Figure 5 above. The longshore elevation gradient that is due to longshore wind is relatively more important for an extratropical storm of large diameter.

In the Mid-Atlantic Bight, extratropical storms that have their centers well to the south of the Bight produce vigorous southwestward flow, while storms with their centers well to the north, although they apply intense local wind stress directed to the northeast, produce little net flow because their effect is balanced mainly by an opposing sea-level gradient. The phenomenon may be explained if one supposes that in such larger storms the cross-shore and the longshore wind effects are roughly equal as far as longshore pressure gradient generation is concerned. With the storm center offshore, nearly complete cancellation may then be expected, while a particularly strong gradient should oppose the longshore wind stress when the storm center is well to the north.

Mean Circulation of a Stratified Fluid

In discussing the development of wind-driven transient flow in a stratified fluid, it was noted that the isopycnals rise or sink in a relatively narrow nearshore band that is scaled by the internal radius of deformation, and they undergo large vertical excursions, even under modest wind stress impulses. If a steady state flow pattern is eventually approached in such a case, the tendency to vertical isopycnal displacement within the same nearshore band should persist and must be counteracted by dissipative processes, mixing, and internal friction. A steady state pattern of upwelling or downwelling circulation then comes into existence in which the vertical advection of temperature and salinity is balanced by mixing across (and along) isopycnals. Modeling of the flow and pressure fields associated with similar phenomena is greatly hampered by our limited understanding of dissipative processes in a stratified fluid. In a recent review article, *Allen* [1980] concludes that similar model studies are all more or less unrealistic for this reason. At the same time, however, these model studies clearly show that a boundary layer of a scale of the internal radius of deformation may well accomplish mass balance closure in somewhat the same way as the frictional boundary layer over a slope (Figure 2 or 4), i.e., accepting Ekman transport over some portions of the coast and supplying it over other portions.

Given the absence of a realistic parameterization scheme for nearshore dissipative processes in a stratified fluid, the simplest step is to ignore them and construct a steady circulation model without friction and mixing. In the absence of mixing and friction, the fluid conserves potential vorticity, and a flow pattern may be calculated without difficulty by using linearized theory. This pattern is illustrated in Figure 6.

In this illustration, the total transport equals the Ekman drift over most of the basin, so that below the Ekman layer the fluid is quiescent. A coastal boundary layer, typically 5–10 km wide, accepts the Ekman drift along the right-hand shore and transports it around the ends of the basin to the coastal boundary layer along the left-hand shore, which supplies the fluid for the interior Ekman transport. The surface remains flat, except within the coastal boundary layers. Along the shores parallel to the wind, a pressure gradient opposes the wind in the upper layer, but the lower layer is entirely quiescent. Correspondingly, the pycnocline has a strong tilt in the longshore direction as well as cross-shore. At the coast, there is exact balance between wind stress and pressure gradient force in the upper layers.

One should not take too seriously the details of this simple linear theory flow pattern. The main point is that the adjustment of the isopycnals to a steady flow pattern may allow a transition from a quiescent interior (except for surface Ekman drift) to an active coastal boundary layer over a distance range of 5–10 km. In particular, a longshore pycnocline tilt may develop, generating a pressure gradient in opposition to the wind in the top layer alone and confined to a coastal band. Dissipative processes would presumably spread out the trapped density field implied by this model to a scale larger than the internal radius of deformation, but the basic character of the pycnocline tilts might well remain as predicted by the model. Along continental slopes, in particular, a considerable range of depth is available for the development of longshore isopycnal tilt.

The monthly average summer circulation in Lake Ontario is sometimes found to exhibit a coastal jet pattern similar to that shown in Figure 6, at least along the south shore. The analysis of IFYGL (International Field Year on the Great Lakes) data for July and August showed that along this shore eastward and westward jets in warm water were associated with a thermocline tilt both cross-shore, for geostrophic equilibrium, and longshore. The longshore thermocline tilt corresponded to a pressure gradient not quite sufficient to balance the wind stress. The north shore pattern was, however, drastically different, and there were also other complexities which, for the present, remain unexplained. Part of the difficulty is probably that long-term fixed-point mean currents do not reflect particle velocities and are physically more or less meaningless.

Many observations of currents, densities, etc., are available during the summer (upwelling) season off the Oregon shelf, and from these a seasonal mean circulation pattern may be pieced together [*Huyer et al.*, 1979; *Mooers et al.*, 1976].

The longshore components of mean velocities are southward at the surface, strong above the inclined density front, and northward below the surface in depths of 100 m or more. The mean velocity of the coastal jet is of the order of 0.3 m/s. The northward flow below is referred to as the poleward undercurrent, and this appears to be trapped over the upper slope in depths less than 500 m.

Cross-shore velocities present a more complex picture and have been the subject of considerable controversy. Some of this was no doubt caused by a confusion of Eulerian and Lagrangian means, an acute problem in an upwelling zone where some fixed point current meters sample widely different water masses in the course of upwelling-downwelling events. What is not in doubt is that over most of the water column the cross-shore velocity is directed shoreward most of the time and has an amplitude of about 2 cm/s. Across the 100-m isobath, this implies onshore transport of about 2 m^2/s, or about 3 times more than the offshore Ekman transport at the surface associated with the mean wind stress. There is also some offshore Ekman transport in the bottom boundary layer of the poleward undercurrent, but it is very unlikely that this is sufficient to maintain two-dimensional mass balance by transporting away most of the onshore flow that arrives throughout the water column. Various studies have also convincingly demonstrated that some of the water drawn from deeper levels is heated at the surface and sinks along isopycnals of the pycnocline when the latter intersects the free surface. This implies offshore motion along some isopycnals, but it is not clear whether the quantity is sufficient to affect the cross-shore mass balance significantly.

A long-term mean onshore velocity of about 2 cm/s, constant with depth, implies a longshore sea-level gradient of 2×10^{-7}, driving northward. A longshore gradient of this sign and magnitude may also be inferred from the density field of the North Pacific [*Reid and Mantyla*, 1976]. In the yearly average, this gradient is confined to latitudes south of 38°N, but in the summer it extends to 44°N, and thus encompasses the Oregon shelf. The cross-shore sea-surface slope associated with the density field extends to about 100 km from the shore, i.e., it coincides with the poleward undercurrent. The longshore sea-level slope is associated with a corresponding pycnocline slope, more or less as in the simple model of Figure 6. The longshore momentum balance of the poleward undercurrent is thus dominated by a northward driving pressure gradient that is balanced in the frictionless interior by onshore flow. Where the onshore flow runs into the continental slope, a northward current develops, with associated bottom friction. The longshore isopycnal slope along the west coast of North America is apparently part of a larger-scale response of the North Pacific to wind stress. The undercurrent transports relatively warm and saline water northward over a considerable range of latitude.

In the surface layers, offshore wind-driven Ekman drift is compensated by onshore flow in a layer of about 30 m depth, i.e., essentially above the main pycnocline. Onshore flow in the deeper layers turns seaward, partly in the bottom boundary layer below the undercurrent, but this circulation is confined only to the trapping width of the boundary current (~50 km), and in any case it is insufficient for two-dimensional mass balance. The rest of the inflow is presumably accommodated in an intensified boundary current in a rather more complex situation than Figure 6 illustrates but nevertheless in the same general manner.

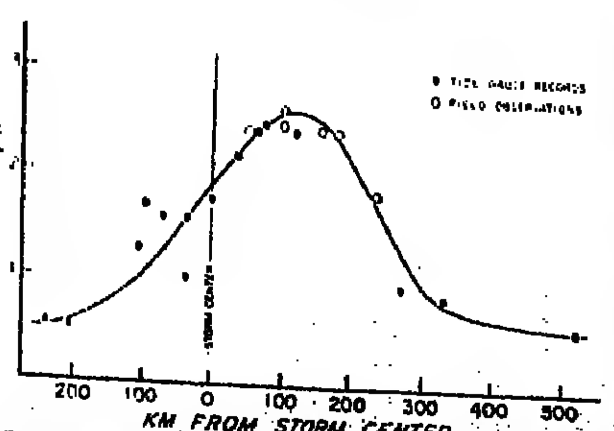

Fig. 5. Sea-surface elevations accompany Atlantic coast hurricanes, from *Redfield and Miller* [1957]. Maximum elevation occurs well to the right of the storm center, looking along the path of the storm as it crosses onto land.

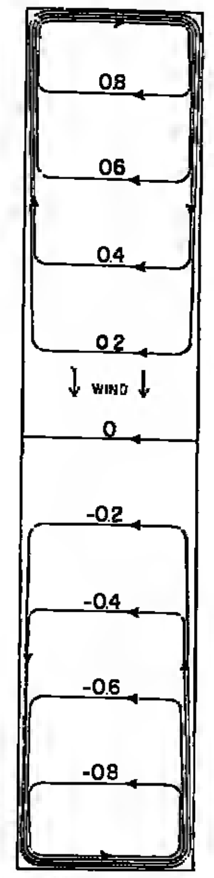

Fig. 6. Steady transport streamline pattern in two-layer fluid contained in a 5:1 rectangular container acted upon by steady wind. Surface-level distribution is flat in the center but is characterized by strong gradients in a coastal boundary layer (scale width, the internal radius of deformation) both cross-shore, for geostrophic balance, and longshore, opposing the wind. (From *Csanady and Scott* [1974].)

Conclusion

The later sections of this article have increasingly focused on long-term, larger-scale flow phenomena, which are at best partially understood. The mean circulation problem clearly requires a further study in all three environments discussed here, as well as in even more complex cases, such as semi-enclosed basins. To quote another conspicuous gap in knowledge, the summer circulation over the East Coast continental shelf shows complexities that, at present, appear completely puzzling, including a bottom-trapped cold band of water flowing along the outer shelf, the water supply for which seems to originate in the Gulf of Maine. On the other hand, we seem to possess a fair understanding of short-term transient flow events over the inner shelf.

Incomplete as our present state of knowledge of coastal circulation may be, it clearly provides a much better basis for assessing the environmental impact of various human activities than was available a few years ago. Present policies and rules of the regulatory agencies do not reflect this, presumably because scientific understanding has not yet been translated into the engineering science of pollution modeling, at least not at the necessary level of sophistication, i.e., focusing on the probabilities of undesirable events rather than on such simplistic measures of nuisance or hazard as the 'mean concentration' of a pollutant, whichever way the mean is defined. It should be well within the realm of possibility to develop the more advanced pollution prediction models required and to distill from the science of coastal circulation the quantitative inputs necessary for these models.

Acknowledgments

This work has been supported by the Department of Energy under a contract entitled Coastal-Shelf Transport and Diffusion. A fuller, more quantitative version will be published in 1981 in *Advances in Geophysics*.

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Reflections From the Executive Office Building

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Editor, Eos

Four years ago, Frank Press came to Washington to take on what amounts to the position of chief scientist for the United States of America. He came to serve a new President as his personal science advisor and to be director of the Office of Science and Technology Policy in the Executive Office of the President. As a new administration takes over in Washington, Frank Press has returned to MIT for a brief respite before assuming, on July 1, 1981, the presidency of the National Academy of Sciences for a 6-year term.

When Frank Press arrived in Washington in early 1977, he was relatively unknown in political circles. He would have to become very well known to the President, to members of the House and Senate committees, to the Office of Management and Budget (OMB), to representatives from industry, and to all departments of the executive branch of government. Frank Press leaves office not only very well known but very well respected as an apolitical human who served effectively among politicians.

His own views of his time in Washington are provided in two recent articles in *Science* magazine (January 9 and 16, 1981). On his last day, in his third-floor office overlooking the north lawn of the White House, Frank Press took time out to describe to us a few of the high points of his last 4 years and to muse on the future for geophysics.

In Washington, Frank Press played two distinctly different but intertwined roles. As the President's science advisor, Frank Press had to put his abilities and those of the scientific community at the service of the President. In this era it is hard to envision a piece of legislation or a regulation that does not require scientific input. It is equally as hard to separate science from economic, regulatory, or defense issues. As director of the Office of Science and Technology Policy (OSTP), Press did not deal primarily with science or scientists but rather with issues that affected science and science policy and with individuals who handle these issues. The rapport he established with OMB contributed heavily to his success. Concepts in government, no matter how noble or valid, become no more than bureaucratic paper if funding does not support them. A sympathetic President and an effective science advisor/OSTP director were behind the fact that science and technology funding fared very well during the past few years.

Frank Press has been a leader throughout his career. In 1957, at age 33, he became director of the Seismological Laboratory of the California Institute of Technology. He was elected to the National Academy of Sciences in 1958. In 1960 he was named California scientist of the year, and in 1962 he was honored by Life magazine as one of the 100 most important young people in the United States. In 1965 he assumed the chairmanship of MIT's Department of Earth and Planetary Science, and he served as AGU president from 1974 to 1978. He has received numerous awards and medals for his scientific achievements.

In addition to issues and concepts the implementation of scientific programs within the federal government and of programs that rely heavily on scientific input were influenced by Press's advice on the selection of key personnel. His quickly established credibility made it automatic to turn to him, and he in turn consistently surveyed the scientific community for opinions and advice both on issues and on personnel. He canvassed individuals and went to various scientific and technical organizations, including societies, for help. Press commented on the role of some of these organizations. Some were effective lobbying groups; others, such as the American Physical Society, prepared excellent analytical reports; and still others were like the AGU, with which he had essentially no formal interaction during his term in the White House. Although societies in the earth sciences have not prepared public policy studies, such as the well-known ones prepared by the American Physical Society and the Academy, he sees that there may be such a role in the future for AGU.

Extraordinarily high-level consideration is required by the far-reaching implications of so many issues that are closely related to science. Press commented on various space missions and about policy-related issues ranging from recombinant DNA to energy policy. Two programs of particular interest to geophysicists are synfuels and ocean margin drilling (OMD). Press noted that the U.S. has sufficient energy resources available but not instantly so. To initiate either significant synfuel production or an ocean margin drilling program, the federal government must support and protect the undertakings. However, neither will function well unless it is ultimately in the hands of industry.

The federal government role is essential because, in the case for synfuel development, for example, an oil cartel could adjust and chop prices in ways that would cripple the incipient industry. In the OMD case the payout is likely to be decades away, and the research could be put off. Industry requires a sharing of the cost if it is to do the work at an earlier stage and thus to bring in knowledge in order to clarify the country's future alternatives. The OMD program would be politically dead today if Frank Press had not been able to bring together government and industry.

The routes by which scientific and technical issues travel from conception to implementation in the government directly influence the outcome. At the highest levels, individuals' backgrounds, skills, and prejudices can become all important. Frank Press was fortunate. His old friend and colleague Harold Brown was secretary of defense, smoothing the way for an extraordinary collaboration in that key area. He was not without other scientific colleagues in high places: for example, AGU members Hans Mark, secretary of the Air Force; Robert Frosch, administrator of NASA; and William Menard, director of the U.S. Geological Survey. Press worked closely with OMB on the science aspects of departmental budgets. He remarked that whenever the secretary of a department, for whatever reason, was behind an issue, the way was clear and everything flowed smoothly. But if for any reason the secretary was not positive, the issue was completely dead. Among the government agencies, Press singled out for special praise the U.S. Geological Survey under William Menard—a highly efficient and thoroughly professional scientific organization that Press feels has received less than the credit due it in the past several years.

In looking at where geophysics is headed in the next few years, Frank Press talked about a golden future, a future full of opportunities in science and opportunities for employment and new careers. He cited the new liaison between geology, geophysics, oceanography, and the planetary sciences and the overriding importance of these areas in dealing with the critical natural resource problems that the nation and the world face. New techniques and scientific discoveries will keep excitement in geophysics at a high pitch for many years. He mentioned specifically the new seismic reflection profiling, such as the COCORP program; hot water circulation in the ocean ridges; the Venus Orbiter Imaging Radar and the Galileo space missions; and high-pressure research as contributing to this excitement. As Press spoke, one sensed perhaps a bit of envy for the young scientist who has before him such extraordinary opportunities to contribute.

In talking to Frank Press one forms a picture of an effective team with perhaps continually changing players, the President, department secretaries, and advisors, dealing with issues and broad policy matters—sometimes effectively and other times less effectively, but always with the national interest foremost. Much of the work Frank Press undertook was effective because the President cared about science and engineering, and the President understood the importance of considering the input of scientists. Frank Press could communicate with the President: 'The President knows what I mean when I talk about the second derivative going to zero.' The effectiveness of Frank Press' service to the President and his role in strengthening science and engineering, two distinct areas both carried out so well, depended not only on a willingness of those in high places to listen but also on affirmative action. Many of the people who worked with Press during the last 4 years will remain on the White House staff. It is our hope that they will transmit to their new bosses, whether they be economists, lawyers, industrialists, or scientists, the importance of including scientific considerations, of seeking out scientific advice, and of keeping the scientific base on which this country grows healthy. Frank Press has established a fine foundation as the first full-term director of the Office of Science and Technology Policy. It remains to his successors to build upon it. We also expect that his successors will hear from him and that in his new role as president of the National Academy of Sciences, which is truly a role in which one represents science and scientific institutions, geophysicists will have cause to be very proud of one of their own.

News

Acid Precipitation

Copies of the draft National Acid Precipitation Assessment Plan are available for public comment from the Interagency Task Force on Acid Precipitation. The plan, which outlines a 10-year national research program, is open for comment until April 3. It supersedes an earlier plan proposed by the former Acid Rain Coordinating Committee (ARCC).

The national assessment program aims to identify the sources, causes, and processes involved with what is commonly known as 'acid rain,' i.e., precipitation with a pH less than 5.7. However, the deposition of acidic substances in the atmosphere is not limited to rainy periods; dry deposition also occurs. Major processes for dry deposition are gravitational settling of coarse particles, impaction of particulate aerosols, and the absorption or adsorption of gases.

Sulfur and nitrogen oxides, emitted from automobiles and coal- and oil-burning power plants, usually take the blame for causing the increased atmospheric acidity. This has prompted some to claim that acid rain is a local or regional problem. Preliminary measurements at remote islands in the Pacific and Indian oceans, however, indicate that acid rain may be a global phenomenon.

Acid deposition was tackled by the ARCC, which was established by President Carter's environmental message in August 1979. In September 1980, the committee issued draft copies of its 10-year plan. Two months before that draft was issued, the Acid Precipitation Act of 1980 was signed into law, creating the Interagency Task Force on Acid Precipitation, composed of 12 federal departments and agencies. In November the new task force incorporated ARCC and, using the ARCC 10-year plan as a baseline, began drawing up a new plan on acid rain research.

The task force's draft is 'less strident and has a more balanced tone' than the ARCC preliminary plan, according to Chris Bernabo, executive secretary of the Interagency Task Force. The new draft also makes fewer assumptions and places 'greater emphasis on uncertainties' about acid deposition, he said. In addition, more attention is given to understanding the atmospheric processes involved in the transportation, transformation, and deposition of acidic materials within the atmosphere, noted Bernabo, who was also the AGU Congressional Science Fellow in 1978–1979.

Nine research tasks are the focus of the plan. Each has a lead agency, with funds budgeted expressly for research, and each has agencies that contribute to the work. NOAA leads two of the nine: The agency is charged with leading the research on analysis and assessment of natural resources of acid deposition and the research on atmospheric processes. The Environmental Protection Agency (EPA) leads research on aquatic impacts of the acid deposition, control technology, and the assessments and policy analysis. The Department of Energy is slated as the lead agency to research man-made sources, while the Department of the Interior heads the work on the deposition monitoring of acid substances and on the effects on materials. Research on terrestrial impacts is assigned to the Department of Agriculture.

Copies of the draft can be obtained from Chris Bernabo, Executive Secretary Interagency Task Force on Acid Precipitation, Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20006. All comments on the draft plan should be directed to Bernabo.

The task force is cochaired by NOAA, the Agriculture Department, and EPA. Also participating are nine other federal departments and agencies: the Departments of Commerce, Energy, Interior, Health and Human Services, and State, the Council on Environmental Quality, NASA, the National Science Foundation, and the Tennessee Valley Authority.—*BTS*

H Gas: Captured at Last?

In the strange world of low-temperature physics, few more unusual phenomena have been discovered than monatomic hydrogen gas. According to a recent report (*New Scientist*, Jan. 1981, p. 204), hydrogen atoms do not tend to pair up to form molecules under special low-temperature cryogenic experimental conditions. The reasons for the existence of atomic hydrogen gas at ultra-low temperature, and for its implications, lie in an understanding of the almost pure quantum mechanical properties. Practical uses of atomic hydrogen will await more knowledge of its properties, but right now, if available in sufficient abundance, atomic hydrogen could be used in maser clocks because it emits highly defined frequencies of microwave radiation at room temperature, and atomic hydrogen gas could be used as an energy conservative fuel, as it recombines to the diatomic molecule. For every recombination between two hydrogen atoms, 4.5 eV of energy are released, which calculates to be over 1 million watts of power per second for 10 grams of atomic hydrogen recombined. The large impulse relative to its light mass could be significant in applications of atomic hydrogen as a rocket fuel. Practical applications aside, the main interest in atomic hydrogen at this moment is in the insight into quantum mechanics that study of its properties may provide. Atomic hydrogen atoms 'abound throughout the universe,' even though not on Earth, and thus quantum effects in space, and the hydrogen-rich planets as well, may be elucidated by results of these studies.

Silvera and Walraven describe helium at low temperatures as almost ideal from a quantum standpoint, but not quite (*New Scientist*, U.S.). Monatomic helium remains only as liquid to temperatures as close to absolute zero as attainable. In the cryogenic range between 2.18 and 0 °K, liquid helium (helium I) changes into the so-called superfluid state (helium II).

Helium II is difficult to contain as it tends to creep up the walls of its container and dribble away. The superfluid flows without viscosity or damping and can pass through small holes and membranes that are impermeable to other liquids. The superfluid state is evidently the finite temperature ground state of zero momentum predicted theoretically by Einstein, and thus study of the properties of liquid helium that has 'condensed' into the superfluid state could offer a unique examination of quantum theory. Problem is, superfluid helium atoms interact strongly, and the interactions prevent analogy with theoretical quantum states. Modern theory cannot provide a description of a strongly interacting liquid such as helium. Monatomic hydrogen, however, could provide a better case for comparison with numerous theories.

The importance of the availability of atomic hydrogen gas in the laboratory is that the results of its study may allow a definitive experimental verification of the relation between the superfluid state and the state predicted by Einstein (known as Bose-Einstein condensation). Hydrogen is predicted to remain a gas, even at 0°K. Being a gas, its density can be reduced so that the interactions between atoms are weak enough to place its behavior within the precepts of modern theory.

Atomic hydrogen actually has been known for many years in the laboratory, but in a highly unstable form produced by the dissociation of molecular hydrogen in an electrical discharge. The new process of producing atomic hydrogen utilizes a magnetic field that draws the atoms like a bar magnet; those with the lowest energy state are drawn to the strongest portion of the field. The process feeds hydrogen atoms from an electrical discharge into a cryogenic cell placed with a superconducting magnet. The hydrogen gas can now be held in the cell for indefinite periods.

The experiments with atomic hydrogen are still in their infancy. It has not been possible yet to produce a gas dense enough to have superfluid properties that are amenable for study. What is being attempted is to increase the density by a factor of 10. When that happens, the fruits of this breakthrough may be realized.—*PMB*

Are There Options for Nuclear Waste?

The problems of storage of nuclear wastes are reaching crisis proportions. Although conceding that a measure of the crises has been caused by the 'enormous emotion' of 'protesting green ecologists,' (*ISR, Interdisciplinary Science Reviews*, *5*(4), 1980), the bottom line is that nuclear wastes have been and continue to be dumped into the oceans and scattered in leaking and leakable containers on the surface. There is a fear among members of the nuclear engineering community that the U.S., under recent government restrictions, has placed itself in a compromising position on the development of nuclear power facilities. One area of concern is that of nuclear waste disposal. Other countries are subject to the same problems and fears. For example, in the Federal Republic of Germany the term 'Entsorgungezentrum' has been coined to describe the total process of reprocessing and disposal of spent nuclear fuel elements. The concern is that spent fuel continues to accumulate because restrictions and laws have affected efforts to resolve the problems of reprocessing and disposal. Right now the environment is subject to damage from the inadequate storage practices of the past. Geoscientists working on the problem of waste disposal await the answers to questions about the projected quantity of waste to be disposed. The options to be explored depend on the volumes to be handled.

Recently, an official of the Department of Energy estimated that the total amount of radioactive waste from nuclear power plants that exist now could fill only the area of a football field, stacked to a height of 10 feet. This appears to be an unexpectedly small volume of material, but not included in this estimate are the huge volumes of military wastes.

Furthermore, emotional protests aside, if the construction of nuclear power plants does increase markedly, the volume of wastes will be much larger. In any case, even the most extreme estimates suggest that the amounts of radioactive waste are manageable.

The necessary number of half-lives for which radioisotopes must be stored is on the order of a 'geologic time scale,' so the options for storage must necessarily involve indefinite time protection factors. One obvious option is to store the waste in space (*Spaceflight*, *22*(182), 1980), where thousands of years of stability should be no problem. The safety factors involved in getting the wastes into space are in question, however, as are the costs. It is important to realize that the risks of handling nuclear power plant materials in conventional operations are very low, even by comparison with the risks of handling other materials (op. cit.). The conclusion, based on current wisdom, is that it will be safe to store the wastes on the surface or in the ground.

A preliminary step in storing nuclear wastes is known as reprocessing; this step is also banned in the U.S. at this time. Reprocessing is a concentration and separation technique to remove some isotopes (especially Pu^{239}) for reuse and to separate high-level from low-level radioactive wastes. Although this step involves the risk of making nuclear materials that would present a potential danger if they fell into the wrong hands, it is thought by some to be a crucial step in disposal planning. One option in the storage scheme for all wastes is to incorporate them in a glass host or crystallize the waste into synthetic mineral structures ('SYNROC'). The purpose is to form a synthetic material that has both high chemical resistance and favorable thermal and other physical properties. As with the other stages of spent-fuel reprocessing, continuing research on synthetic host materials is needed.

Considering the constraint that nuclear wastes must be stored and isolated safely for at least 1000 years, it would appear that the choices are few, but this is not necessarily true. Surface (or slightly subsurface) storage is a viable option. There are and will be many types of concentrated radioactive materials located on the earth's surface. It might be argued that they would be in the way of human progress and would be too accessible. Improved canisters of synthetic rock could be kept under control, however, and knowledge of their existence could be transmitted to future generations. Their very accessibility could be an important factor, not only in their safety but in their possible future reuse, when and if more economical isotope separation methods are developed. The difficulty lies with the 'human factors,' particularly public acceptance of almost visible storage practices.

'In or under the surface' includes land, oceans, and ocean floors. The practice of allowing liquid radioactive wastes to flow directly into the sea would appear to be completely unacceptable at all levels. Containment, even in its present state of development, is so much safer. It may be possible to drop projectile-shaped containers into the ocean to penetrate the sediment. There are suggestions, currently under consideration, to place waste-filled containers in holes drilled through the ocean sediment into basalt. The environmental impact of all ocean storage schemes may be unacceptable, however. Perhaps the best alternative for underground storage known today may be in stable geologic formations such as salt domes, as was first tried in the U.S. in the 1950's.

The domes are known to persist stably for hundreds of millions of years and the salt seals out the intrusion of groundwater. Caverns excavated in salt domes last indefinitely, and the salt itself, being a good thermal conductor, is a favorable sink for radioactive heat. According to a recent report (*ISR, Interdisciplinary Science Reviews*, loc. cit.) of tests done at the Asse abandoned salt mine in Germany, totally reliable techniques exist for the safe disposal of wastes of all levels of radioactivity.

It appears clear that, barring public outcry and government intervention, the path to safe storage of nuclear wastes is straightforward, and the best options are beneath the surface, either in salt mines or in the shafts of excavated rock formations. Continuing research on reprocessing of wastes, including the incorporation of separated fractions in synthetic rock or glass; on the geology, geophysics, geochemistry, and hydrology of suitable sites; and on the storage containers will be needed to provide data as the storage builds.—*PMB*

NACOA Vacancies Filled

Six scientists were recently appointed to the President's National Advisory Committee on Oceans and Atmosphere (NACOA) as part of the committee's normal rotation, according to Steven Anastasion, executive director. Two of the six positions were reappointments.

The committee, consisting of 18 scientists not working in the government, advises the executive and legislative branches on federal programs dealing with the oceans and atmosphere. Each member serves for 3 years; six positions become vacant each year as part of the rotation system.

The committee meets about every 6 weeks. Currently under consideration is an evaluation of the role the oceans play in waste-management strategies, Anastasion said. In addition, NACOA will examine national goals and objectives of research and management of the oceans and atmosphere.

Warren W. Washington, chairman of the IUGG Subcommittee for the International Association of Meteorology and Atmospheric Physics, was reappointed to a second term on NACOA. Also reappointed was Sherron Stewart, commissioner of the Texas Deep Water Port Authority.

The four new appointees are Burt Keenan, chairman of the board and chief executive officer of Offshore Logistics, Incorporated, in Louisiana; Jay Lanzillo, industry representative of Chatham Seafood Corporation in Massachusetts; George Tapper, president of Tapper and Company in Florida; and Charles Warren, president of Charles Warren Associates in California. Warren was the first chairman of the Council on Environmental Quality under President Carter.—*BTS*

Saving For a Rainy Day

Critics of solar energy repeatedly point to the technology's ineffectiveness at night or during cloudy days. Proponents argue that storage systems can provide the necessary backup, but the critics counter that the development of storage systems will slow solar energy's growth and add to the already high cost per kilowatt. Now a National Research Council committee adds its voice to the chorus.

The Solar Panel of the Committee on Advanced Energy Storage Systems says that the need for storage systems will not delay solar energy development. 'Present growth for most applications can proceed in the short run as expected. Delays may occur, however, with 'stand alone' electricity-generating systems, which are not connected to a utility network.'

Because solar energy relies on the sun, certain regions of the United States that do not continuously attract sun worshippers could not depend on the technology as a constant and sole energy source; nighttime energy demands also require some backup or storage system. Storage is now limited to facilities that use excess power in off-peak hours to pump water into reservoirs. That water is then released to turn hydroelectric turbines when demand for electricity is high. Geography limits this type of storage.

The Department of Energy's 'ongoing R&D programs on such technologies as underground pumped hydro, compressed air, and advanced batteries will, if successful, facilitate the market penetration of solar-derived electricity,' the committee says in a recent report. More utilities would then be able to install storage systems.

The committee recommends that storage R&D efforts be focused on long-term options that will be responsive to both the economic and technical requirements of high-solar-penetration energy systems. More knowledge is needed, in the committee's opinion, about the social factors—public preferences or perceptions—that could influence the acceptance of solar energy and storage systems.—*BTS*

Mountain Research

The newly incorporated International Mountain Society (IMS) will in May begin publication of an interdisciplinary scientific journal, *Mountain Research and Development*. The quarterly will be copublished with the United Nations University; additional support will come from UNESCO.

A primary objective of IMS is to 'help solve mountain land-use problems by developing a foundation of scientific and technical knowledge on which to base management decisions,' according to Jack D. Ives, president of the Boulder-based organization. 'The Society is strongly committed to the belief that a rational worldwide approach to mountain problems must involve a wide range of disciplines in the natural and human sciences, medicine, architecture, engineering, and technology.'

'Mountain,' as used by the new society, covers a lot of ground. They interpret the term to include uplands and steep slopes at lower elevations, as well as the peaks and ranges.

IMS expects to prepare an inventory of institutions conducting research on mountain areas and a register of individuals possessing what the society judges as the professional, technical, and/or scientific skills applicable to mountain environments.

Officers of IMS include the president and two vice presidents: Cornelie Jest of France and Heinz Loffler of Austria. A council of scientists, engineers, architects, and administrators also guides the society.

For information about membership and journal subscriptions, contact IMS, P.O. Box 3148, Boulder, Colorado 80307.

Geophysicists

Frederick

Thomas M. Donahue, chairman of the department of atmospheric and oceanic sciences at the University of Michigan, was awarded the Arctowski Medal by the National Academy of Sciences 'in recognition of his fundamental contributions to understanding the role of solar radiations in the physics and chemistry of the atmospheres and ionospheres of the Earth, Mars, and Venus.' The medal accompanies a $5000 prize.

Doyle G. Frederick will serve as acting director of the U.S. Geological Survey until a new director is selected. He joined the USGS in 1973 and has served as associate director since February 1980. He has also been the associate chief of the survey's National Mapping Division.

Donald F. Gatz has been appointed head of the new atmospheric chemistry section of the Illinois State Water Survey. He is a member of the statistics faculty at the University of Illinois.

James P. Gibb has been appointed head of the new groundwater section of the Illinois State Water Survey. He joined the Water Survey in 1968.

Gerald J. Wasserburg, at the California Institute of Technology's division of geology and planetary sciences, was awarded the Arthur L. Day Prize and Lectureship by the National Academy of Sciences in recognition of his work with isotopes, studying geophysical problems of the solar system.

The following reports changes in the executive staff of the American Meteorological Society (AMS) and reports awards presented at the annual awards banquet in San Diego.

Richard E. Hallgren, director of the National Weather Service, National Oceanic and Atmospheric Administration, has been chosen president-elect of AMS. He will assume office in 1982.

Robert G. Fleagle, atmospheric sciences professor at the University of Washington in Seattle, is the incoming AMS president. He succeeds *Robert M. White*, president of the University Corporation for Atmospheric Research.

The five councilors elected to 3-year terms of office are: *James Philip Bruce*, assistant deputy minister of the Environmental Management Service, Fisheries and Environment Canada; *Edward M. Carlstead*, chief of the Forecast Division, National Meteorological Center of the National Weather Service; *David S. Johnson*, assistant administrator for satellites, NOAA; *Norman J. Rosenberg*, professor and director of the Center for Agricultural Meteorology and Climatology, Institute of Agriculture and Natural Resources, University of Nebraska at Lincoln; and *Stanley L. Rosenthal*, director of the National Hurricane Research Laboratory, NOAA.

Roscoe R. Braham, Jr., was awarded the Carl-Gustaf Rossby Research Medal, the highest honor accorded by AMS. The professor in the Department of Geophysical Sciences at the University of Chicago was selected 'for his notable contributions in research and effective leadership in the study of complex convective systems.'

Thomas H. Vonder Haar, professor and head of the Department of Atmospheric Sciences at Colorado State University, and *Charles D. Keeling*, oceanography professor at the Scripps Institution of Oceanography, shared the Second Half Century Award.

Jerome Namias, an oceanographer at Scripps, received the Sverdrup Gold Medal 'for his studies of the ocean's role in climatic variability. His long-term dedication to large-scale, air-sea interaction and inspiring leadership has laid the basis for present progress.'

Stanley A. Changnon, Jr., chief of the Illinois State Water Survey, received the Cleveland Abbe Award for his work on the impacts of weather and climate on humanity.

Charles L. Hosler, Jr., received the Charles Franklin Brook Award for outstanding services to AMS. He is a meteorology professor and dean of the College of Earth and Mineral Sciences at the Pennsylvania State University.

Julian P. McCreary, Jr., an assistant professor of physical oceanography at Nova University's Ocean Sciences Center in Dania, Florida, received the Editor's Award for his reviews of manuscripts submitted to the *Journal of Physical Oceanography*.

William M. Frank was chosen as the recipient of the Banner I. Miller Award for contributions to the science of hurricane and tropical weather forecasting. He is an assistant professor in the Department of Environmental Sciences at the University of Virginia.

New Publications

New Listings

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Sedimentation in Oblique-Slip Mobile Zones, *Spec. Publ. 4 Int. Assoc. Sedimentol.*, P. F. Ballance, H. G. Reading (Eds.), Blackwell Scientific Publications, Boston, Mass., vi + 265 pp., 1980.

Soil Chemistry, H. L. Bohn, B. L. McNeal, G. A. O'Connor, John Wiley, New York, xiv + 329 pp., 1979, $19.95.

Stratigraphic Lexicon of Libya, *Bull. 13*, S. Banerjee, Industrial Research Centre, Socialist People's Libyan Arab Jamahiriyah, Tripoli, xviii + 300 pp., 1980.

Thunderstorms, *Develop. Atmos. Sci 12*, C. Magono, Elsevier, New York, x + 261 pp., 1980.

The Upper Cretaceous-Tertiary Formations of Northern Libya: A Synthesis, *Bull. 12*, M. F. Megerisi, V. D. Mamgain, Industrial Research Centre, Socialist People's Libyan Arab Jamahiriyah, Tripoli, x + 85 pp., 1980.

U.S. Earthquake Observatories: Recommendations for a New National Network, National Academy Press, Washington, D.C., xvii + 122 pp., 1980.

Volcanoes, R. Decker and B. Decker, W. H. Freeman, San Francisco, Calif., ix + 244 pp., 1981.

Water Resource Systems Planning and Analysis, D. P. Loucks, J. R. Stedinger, D. A. Haith, Prentice-Hall, Englewood Cliffs, xiv + 559 pp., 1981, $29.95.

Western Water Resources, Coming Problems and the Policy Alternatives, Federal Reserve Bank of Kansas City, Westview, Boulder, Colo., 1980, $25.00.

Physical Oceanographer. The Department of Marine Science and Engineering, North Carolina State University, has an immediate opening for a postdoctoral research associate. Research will be directed toward equatorial circulation dynamics, including seasonal and higher-frequency variability. Participation in fieldwork will be required. Qualifications include a Ph.D. or equivalent in physical oceanography or geophysical fluid dynamics and experience in the analysis of oceanographic time series. The initial appointment will be for 2 years, with a possible continuation subject to availability of funds. Salary is competitive and negotiable, based upon qualifications. Applicants should send the names of three references, a resume, and publication list to Robert H. Weisberg, Department of Marine Science and Engineering, P.O. Box 5923, NC State University, Raleigh, NC 27650.

Faculty Position: University of Iowa. The Department of Physics and Astronomy anticipates one or two openings for tenure track faculty in August 1981. Research specialties for which substantial resources are available are magnetospheric and auroral physics and space and laboratory plasma physics, both theoretical and experimental. Other specialties of interest are astronomy, astrophysics, elementary particle physics, atomic physics, condensed matter, and low energy nuclear physics. The positions involve undergraduate and graduate teaching, guidance of research students, and personal research. Interested persons should send a résumé, a statement of research interests, and the names of three professional references to **Search Committee, Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242.**

The University of Iowa is an equal opportunity/affirmative action employer.

Meteorologist/Remote Sensing. Immediate opening for meteorologist interested in investigating retrieval and modeling of sea surface temperatures and other ocean meteorological parameters from microwave data. Candidate must have post graduate training in meteorology and interest in remote sensing. Salary negotiable depending on experience. Send resumes to: Rodger Smith, Manager of Staffing, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, MD 20840. An equal opportunity employer.

Seismologist. The Tennessee Earthquake Information Center (TEIC) is seeking applications for the position of seismologist beginning July 1981. The position will also be a joint tenure track appointment in the Department of Geology. Primary duties, however, are with TEIC; teaching will be on a time-available basis, not to exceed one course per semester.

The Ph.D. is required and experience with telemetry networks is highly desirable. The successful applicant will be expected to assume co-PI responsibilities on the Memphis and Southern Appalachian seismic networks, as well as actively pursue externally funded research projects. Digital data processing, seismic hazard assessment and public information are other aspects of the job.

The TEIC is a research organization of Memphis State University and the State of Tennessee, 12-month salary ($25,000 and above) depends on background and experience. Position is ¾ state supported, ¼ (summer) from external sources.

Application deadline: 15 April 1981. Send resume, publications list, short statement of research interests, and names and addresses of four referees to:

Arch Johnston, Director
Tennessee Earthquake Information Center
Memphis State University
Memphis, Tennessee 38152

Memphis State University is an equal opportunity/affirmative action employer.

Postdoctoral Research Associate. Oceanography Department of the Naval Postgraduate School seeks recent graduate to study the hydrodynamics, through numerical ocean modeling of the physical oceanographic processes active in the vicinity of the arctic ice edge off Alaska. Problem areas include the effects of the complex bathymetry on the circulation and frontal formation, the dynamics associated with interleaving of water masses at the ice edge, and the mechanisms involved in ice retreat. Research will be performed in the context of an observational program which has acquired data and developed insights over the course of several years.

Position is available March 1981 and is renewable annually. Salary depends upon qualifications. Send resume and the names and addresses of three references to Faculty Search Committee, Dept. of Oceanography, Naval Postgraduate School, Monterey, CA 93940.

Equal opportunity/affirmative action employer.

Vincent C. Kelley and Leon T. Silver Graduate Fellowships

THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico invites applications for the Vincent C. Kelley and Leon T. Silver Graduate Fellowships. The fellowships will be awarded on the basis of the scholastic record and academic promise of graduate applicants. Each fellowship will provide for a generous living stipend of $1,000/month for 9 to 12 months, and up to $2,000/year for travel and research expenses. The Caswell Silver Foundation will pay all tuition and university fees. The awards are made on an annual basis, but may be renewed for up to three years as long as the student maintains excellent academic standing and shows evidence of significant progress in research. Preference will be given to, but is not restricted to, applicants for the Ph.D. program.

An application for admission to the UNM Graduate Program, transcripts, Graduate Record Exam results (verbal, math & geology), three letters of reference and a brief statement of research goals are required for consideration for the fellowships. Application materials may be obtained from:

Rodney C. Ewing
Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

The deadline for applications is April 1, 1981 for the Fall semester of 1981.

The Caswell Silver Distinguished Professorship in Geology

THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico is pleased to invite nominations or applications for the Caswell Silver Distinguished Professorship in Geology. This endowed professorship shall be awarded for periods of up to two years to earth scientists of distinguished accomplishment and international reputation. The professorship may be held by scientists of all specialities of the earth sciences in the broadest sense, and the major criterion for selection is that the individual be an active, productive leader in his or her field of research. The recipient must carry out a vigorous research program while in residence at UNM. The recipient is expected to interact with the faculty and students of the Department and to provide one or more seminars, in an advanced topic of his/her choice, during each academic year. The Foundation will provide unusually advantageous remuneration commensurate with the distinguished nature of the appointment. In addition, a generous allocation for travel and operating expenses (to include secretarial support, analytical services in department laboratories, use of field vehicles, and preparation of manuscripts) will be provided.

Applications or nominations should include a detailed resume and brief statement of major research accomplishments. Applications or nominations should be forwarded to:

Rodney C. Ewing, Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

The Caswell Silver Foundation is an equal opportunity employer.

Von Braun Post-Doctoral Fellowship in Space Physics/University of Alabama in Huntsville. Appointment effective September 1981 in a tenure track assistant professorship with reduced teaching load during the first two years. Research specialty in astrophysics, planetary science or solar terrestrial physics. Research support available from UAH, NASA and Redstone Arsenal. Salary competitive. Recent Ph.D.s are invited to send resume, research plans and names of four references. Apply to: Von Braun Fellowship Committee, Office of Academic Affairs, University of Alabama in Huntsville, AL 35899.

Equal opportunity in education and employment.

Solid Planet Geophysicist/Texas A&M University. The Department of Geophysics at Texas A&M University is pleased to announce availability of a junior level, tenure track faculty position. The department emphasizes solid earth geophysics with concentrations in tectonophysics, geodynamics and internal structure. We are seeking a talented and active researcher and teacher who will complement, strengthen, and broaden current areas of expertise. There are excellent opportunities for interaction and collaboration with members of our department as well as those in the departments of oceanography and geology and in the center for tectonophysics. Qualified scientists are requested to send resumés to Neville L. Carter, Head, Department of Geophysics, Texas A&M University, College Station, TX 77843.

Texas A&M University is an equal opportunity employer.

Postdoctoral Appointee. Applications are invited for a recent graduate to perform research on the exchange of gasses and fine particles between the atmosphere and the surface of the earth. A Ph.D. in meteorology or a related discipline is required and strong research interests in experimental micrometeorology is highly desired. Familiarity with instrumentation, electronics, and computer programming is needed. The individual will join a closely-knit research group operating under DOE and EPA sponsorship. Please send resume to: Mr. Mickey Brown, Box RER-80, Argonne National Laboratory, 9700 So. Cass Avenue, Argonne, IL 60439.

An affirmative action/equal opportunity employer. Women Minorities, the handicapped and veterans urged to apply.

Groundwater Hydrologist and Associate/Assistant Professor, tenure-leading. Develop and conduct a strong research program (75%) in groundwater hydrology as related to irrigation. Perform research on the effects of various irrigation management programs on soil water movement and groundwater storage. Might include modeling the hydrologic system associated with the unsaturated volume below the crop rooting zone as well as the water saturated portion. Also teach (25%) two advanced groundwater hydrology courses and basic descriptive hydrology course. Requires Ph.D. in engineering, hydrology, geology or related field with strong background in mathematics, flow in porous media, computer science, groundwater hydrology, optimization and irrigation. Apply with resume and three names of references by April 1 (or until suitable candidate is found thereafter) to: Dr. William L. Powers, Director, Nebraska Water Resources Center, 310 Agricultural Hall, The University of Nebraska-Lincoln, Lincoln, NE 68583. Affirmative action/equal opportunity employer. (402) 472-3305.

Structural Geologist. The Department of Geosciences at Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses, and pursue an active research program. Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and engineering geology and has a close working relationship with the geotechnical group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for application is April 1, 1981. Applicants should send a resume, the names, addresses, and telephone numbers of three referees, and a brief statement of research interests to R. H. McCallister, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

Program Manager/Meteorology. Oceanographic Services, Inc., is seeking qualified applicants for the position of program manager for meteorological studies. Applicants should have an M.S. or Ph.D. in meteorology or atmospheric sciences, plus experience in the field. A broad general knowledge of air pollution, and an understanding of the air pollution regulatory environment, is helpful. Interested persons should send resume, references, and salary history to R. C. Banks, Oceanographic Services, Inc., 25 Castilian Drive, Goleta, CA 93117.

Geophysicist North Carolina State University—Raleigh. The Department of Marine, Earth and Atmospheric Sciences invites applications for a presently available tenure track position in geophysics. Rank and salary are open, depending on qualifications and experience. A Ph.D. is required. Applied or exploration geophysics orientation are preferable; however, other specializations in geophysics also will be considered. Primary responsibilities will include generating and conducting research programs as well as teaching graduate courses in geophysics. The department currently consists of 31 regular faculty members including 15 in the areas of geology and geophysics. Please send resume and names of three references to Prof. I. J. Won, Search Committee Chairman, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27650, USA. We hope to make a final decision prior to May 31, 1981.

North Carolina State University is an equal opportunity/affirmative action employer.

Seismologist and Specialist in Rock Deformation Science: Bernard Price Institute of Geophysical Research, University of the Witwatersrand, Johannesburg, South Africa. Applications are invited from suitably qualified persons, regardless of sex, race, religion or national origin, for appointment to the above posts. Mines in the Witwatersrand Gold Fields are now penetrating to depths of 4 km. The confining strata are strong quartzites. Between 1971 and 1977 the Institute had an active programme of investigating the seismic events which accompany the deep mining. Many seismological studies were published on these events. Occasionally tremors have exceeded a magnitude 5.0 on the Richter Scale and in recent years there have been ten events between M = 4.0 and 4.6. Source mechanisms are similar to those of small shallow earthquakes.

One of the Institute's publications (by Gay and Ortlepp) describes a region where a seismic event occurred in advance of active mining. Special excavations were created to examine the failure zone and it was possible to ascertain in some detail the structure of this volume of failed rock.

There are heavily instrumented seismic networks—some completely digital—in four of the mining areas. Mine safety records are comparable with major industrial operations on surface.

The University is now renewing its researches on the seismic source mechanism and its implications. We seek a seismologist and a specialist in rock deformation science, to lead further researches in this important sphere, and to collaborate with institutions and University Departments elsewhere in the world who have a special interest in the mechanics of shallow earthquakes. The salary is negotiable, depending on qualifications and experience. Applications should reach the Director, Bernard Price Institute (Geophysics), University of the Witwatersrand, Jan Smuts Avenue, Johannesburg 2001, South Africa before 31 March 1981; further information on this post may be obtained from him.

Geochemistry/Brittle Deformation, University of New Brunswick. The Department of Geology has a tenure track position available from July 1, 1981 at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students.

Applications will be accepted in the following fields: geochemistry of ore bodies, exploration, environmental or soil geochemistry, brittle deformation, rock mechanics or site engineering.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Faculty Position: Petrology Tectonics. The Department of Geology at Stanford University has an opening for a full professor to work half-time in the fields of petrology and tectonics. We seek someone who is interested both in teaching and in conducting research on the petrology and tectonics of continental margins. Applicants are invited to send letter of application, a resume and the names of three references by March 31, 1981 to:

Allan Cox
School of Earth Sciences
Stanford University
Stanford, CA 94305

As an equal opportunity and affirmative action employer, Stanford welcomes applications from women and minorities.

Queens College. Position for 1-2 years as sabbatical replacement starts September 1981. Specialties requested: geochemistry (organic, environmental, or exploration); exploration geophysics; groundwater geology. A Ph.D. required. Applications should include c.v. and three references. Send to O. H. Speidel, Department of Earth and Environmental Sciences, Flushing, NY 11367.

Queens College is an affirmative action/equal opportunity employer.

Sedimentology: University of Minnesota. The Department of Geology and Geophysics invites applications for a temporary faculty position in recent sediments starting September 1981. This is likely to become a tenure track assistant professor position starting fall 1982. Opportunities exist for interaction with the Limnological Research Center and with active research programs in paleoecology, paleomagnetism, hydrogeology, and low-temperature geochemistry, as well as with the St. Anthony Falls Hydraulic Laboratory. Ph.D. and strong interest in research are required. Resume, statement of research interests, transcripts, and three letters of recommendation should be sent by March 26 to:

Dr. Anita L. Grews
Sedimentology Search Committee
Department of Geology and Geophysics
University of Minnesota
108 Pillsbury Hall
Minneapolis, MN 55455

The University of Minnesota is an equal opportunity educator and employer and specifically invites and encourages applications from women and minorities.

Director: Meteorology Division, Air Force Geophysics Laboratory. Air Force Geophysics Laboratory invites applications for the position of Director of the Meteorology Division located at Hanscom Air Force Base, Massachusetts. The Division is responsible for Air Force research and development in meteorology, atmospheric physics, remote and direct sensing technology, climatology, and related technologies. The division director provides overall direction to an R&D program which employs over 80 people and covers a broad range of in-house and contractual scientific investigation. A candidate should have a record of distinguished achievement in meteorology/atmospheric physics as a research scientist and manager of a substantial R&D unit. This position is Air Force Senior Executive Service with a salary range of $52,247 to $57,673, subject to current $50,112 ceiling. For an application package, call collect: Robert Ellerin, (617) 861-2896. To be considered, applications must be returned by 30 April 1981.

Equal employment opportunity employer.

Faculty Position Economic Geology

The Department of Geology, University of Georgia, has a tenure track opening in economic geology. Rank and compensation are open through the associate professor level.

Duties include (1) teaching courses in exploration geochemistry (2) supervising M.S. and Ph.D. candidates, and (3) developing a strong research program with significant field commitment.

Teaching and research interests in one or more additional fields such as ore deposit mineralogy, reflected light microscopy, theoretical geochemistry of ore deposits, fluid inclusion research, hydrogeochemistry, or environmental geochemistry are desirable.

An applicant should submit a detailed curriculum vitae and have at least three letters of recommendation sent to F. Donald Eckelmann, Head, Department of Geology, University of Georgia, Athens, Georgia 30602.

The deadline for receipt of applications is May 1.

The University of Georgia is an equal employment opportunity/affirmative action institution.

Postdoctoral Fellowship in Experimental Petrology at UCLA. Starting approximately September 1, 1981, an up to 24-month appointment in phase equilibrium research, chiefly hydrothermal synthesis, will be available. Candidates should possess Ph.D. Send letter of application and arrange for two confidential recommendations to be forwarded to: W. G. Ernst, Earth and Space Sciences, University of California, Los Angeles, California 90024.

UCLA is an equal opportunity/affirmative action employer.

Upper Ocean Modeler. Two postdoctoral positions in upper-ocean modelling available in the mesoscale air-sea interaction group at the Florida State University. Ph.D.'s with background in fluid dynamics, theoretical physical oceanography, dynamic meteorology, numerical analysis, or physics are invited to apply. Salary range $19,000–$21,500/year. Positions are supported by Office of Naval Research and may be filled at any time after April 1, 1981. Send vitae and names of three references to Professor James O'Brien, The Florida State University, Tallahassee, FL 32306.

The University is an equal opportunity employer.

Dean of Sciences and Mathematics/Hunter College, City University of New York. Challenging position available July 1981, in dynamic urban institution. Strong doctoral research programs, extensive federal funding, major commitment to women and minorities, MBS and MARC programs, stable enrollments, major expansion of facilities in progress, attractive midtown Manhattan location. Send resume and names of three references to Chair, Search Committee for Dean of Sciences and Mathematics, Box 447, Hunter College, 695 Park Avenue, New York, NY 10021.

Research and Data Systems, Inc./Scientific Programmers and Programmer Analysts. Immediate openings for persons with B.S. in science or math and at least two years experience with FORTRAN or PL1 on IBM systems. Work involves data processing and analysis from satellite based remote sensing systems. Experience with time sharing systems preferred. Also have openings for staff scientists with strong programming background. Send resume in confidence to Research and Data Systems, Inc., 9420 Annapolis Road, Lanham, MD 20801. Telephone: (301) 459-0001.

Geophysicist/Structural Geologist, Albion College. A tenure track position, commencing Fall 1981, is open at the assistant professor level at Albion College's Department of Geological Sciences. The position involves teaching undergraduate laboratory courses in structural geology and geophysics and introductory lab courses or non-lab courses in geology. The Department is developing a geophysics/geology major and has some geophysical equipment. Candidates with a Ph.D. or who are about to acquire a Ph.D. are preferred.

Depending upon the applicant's background, the new staff member may have the opportunity to assist in teaching at Albion's geology field camp for additional remuneration. A 6-week summer field methods course is offered to students from many colleges and universities at the field camp located in the Front Range near Boulder, Colorado.

Albion College is a co-educational liberal arts college located in southern Michigan, an hour's drive from Michigan State University, The University of Michigan and Western Michigan University. The Department has four staff members and 30 to 40 majors; it is a well-equipped department occupying a floor-and-a-half of a new science center.

Resume, transcripts and three letters of reference should be submitted to: Prof. Lawrence O. Taylor, Department of Geological Sciences, Albion College, Albion, Michigan 49224.

Albion College is an equal opportunity employer.

Exploration Geophysicist/University of Oklahoma. The School of Geology and Geophysics at the University of Oklahoma will hire an experienced exploration geophysicist to fill the Frank and Betty Schultz Professorship, and is seeking nominations and applications for the position. The person must be a distinguished scientist who has made important contributions to exploration geophysics through research. Preference will be given to a scientist whose specialty is seismic properties of earth materials and who has earned the Ph.D. The Schultz Professor will provide leadership and guidance in establishing a quality teaching and research exploration geophysics group. The University of Oklahoma has recently made a strong commitment to the earth sciences with the establishment of a College of Geosciences, to be housed in a new building. The School of Geology and Geophysics will expand from its present faculty of 16 to 26 faculty members by 1986. This will include three scientists in the exploration geophysics area, five in structure-tectonophysics-solid earth geophysics and others in stratigraphy-paleontology, geochemistry-petrology, and energy resources.

Applications are due April 30, 1981. Inquiries, nominations, and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma is an equal opportunity employer.

Oceanographic Mooring Technician. The Marine Science Program at North Carolina State University (Raleigh) is expanding its oceanographic technical services group and is currently seeking a technician familiar with the design and deployment of deep-sea current meter mooring arrays, as well as with standard shipboard oceanographic sampling techniques.

Qualifications include a degree in science or engineering with some electronics background and two years field experience or an equivalent combination of education and experience. Salary commensurate with education and experience. Send resume and names of references to Personnel Services, North Carolina State University, P.O. Box 5067, Raleigh, NC 27650.

An equal opportunity employer.

SERVICES

Geothermal Resource Maps. The Department of Energy, Division of Geothermal Energy (DOE), in cooperation with NOAA's National Geophysical and Solar-Terrestrial Data Center, announces the publication of geothermal resource maps of Idaho, Colorado, Utah, New Mexico, and California, as well as a "Thermal Springs List for the United States." These publications are part of the DOE's State Resource Assessment program. These maps are designed to communicate to a user the relationship of natural thermal features, thermal wells, and areas considered to have a high probability of encountering additional geothermal resources to cultural features and land-use categories, such as parks, wilderness areas, national forests, Native American lands, and Department of Defense reservations.

State geothermal resource maps of Washington, Montana, North Dakota, Texas, Oregon, Arizona, Nevada, Wyoming, Virginia, Nebraska, Alaska, Kansas, Oklahoma, and Hawaii will follow in the future.

If you wish to obtain these products, send your name or card, your affiliation, and your address to: NOAA/NGSDC, Data Mapping Group, Code D64, Boulder, CO 80303.

Meetings

Gordon Research Conferences

Four of the Gordon Research Conferences scheduled for this summer will include discussions of interest to geophysicists. Emphasis at each conference is on the free exchange of ideas. One requirement of the conferences, for example, is that no information presented be used without the specific authorization of the individual making the contribution. The conferences, initiated by Neil E. Gordon 50 years ago, are self-supporting.

A session entitled 'Environmental Sciences: Air,' is scheduled for June 15–19 at the New Hampton School in New Hampton, New Hampshire. Jack G. Calvert will chair the conference.

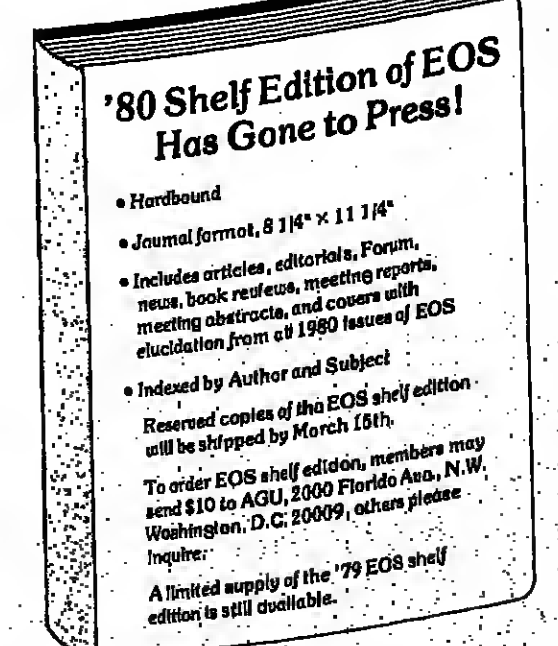
Martin Walt will chair the conference on 'Collisionless Shocks in Space, Astrophysical, and Laboratory Plasmas,' scheduled for June 22–26 at the Brewster Academy in Wolfeboro, New Hampshire.

'Fluids in Permeable Media: Physics and Chemistry' will be the topic of the conference August 3–7 at the Tilton School in Tilton, New Hampshire. R. L. Reed and R. S. Schechter will preside.

Marco T. Einaudi and Hiroshi Ohmoto will cochair the session on inorganic geochemistry, slated for August 17–21 at Colby-Sawyer College in New London, New Hampshire.

Attendance at each conference is limited to about 100 conferees. Application forms, available from the director's office, must be submitted in duplicate. A registration card will be mailed to those selected. Advance registration is then required.

Applications and additional information can be obtained from Alexander M. Cruickshank, Director, Gordon Research Conference, Pastore Chemical Laboratory, University of Rhode Island, Kingston, Rhode Island 02881.



The Fourth Conference on the

Physics of the Jovian and Saturnian Magnetospheres

will be held at the

Applied Physics Laboratory
The Johns Hopkins University

October 22 – 24, 1981

Voyager I and 2 and Pioneer II Results and Theoretical Interpretation will be Emphasized

Program Committee:

M. Acuna	(Goddard Space Flight Center)
T. D. Carr	(University of Florida)
T. W. Hill	(Rice University)
D. M. Hunten	(University of Arizona)
S. M. Krimigis	(Johns Hopkins University)
F. L. Scarf	(TRW Systems)
G. L. Siscoe	(University of California)
E. C. Stone	(California Institute of Technology)
J. A. Van Allen	(University of Iowa)

For further information, please contact:

S. M. KRIMIGIS
APPLIED PHYSICS LABORATORY
THE JOHNS HOPKINS UNIVERSITY
LAUREL, MARYLAND 20810

(301) 953-7100 X3252

Call For Papers

AGU is issuing a call for papers for the 28th Pacific Northwest Regional Meeting to be held at Central Washington University, Ellensburg, Washington, on September 17–18, 1981.

The purpose of the regional meeting is twofold: to inform the geophysical community about the research conducted within the region, regardless of the specialty, and to report what is known about the region, regardless of the location of the individual or institution conducting the research. Progress reports and student papers are encouraged. Field trips are planned for before and after the meeting to examine the strike-slip faulting in the Cascade Range and Columbia Plateau.

Symposia

Special symposia will be held on 'The Tectonics of the Columbia Plateau and Other Neogene-Quaternary Faults of the Pacific Northwest,' on 'Stratigraphy and Structure of the Cascade Range,' and on 'Studies of the Eruption of Mount St. Helens.'

Accommodation and Travel Information

Central Washington University is located 2 miles north of Interstate 90 in Ellensburg, Washington, 40 miles north of Yakima, and 110 miles east of Seattle. The Yakima airport is served by Republic and Cascade airlines, with connecting flights to Seattle and Portland. On request, shuttle vans will be provided from the Yakima Airport to Central Washington University. Accommodations will be available at CWU Conference Center at low costs.

Plans for field trips that will begin in Portland on September 14 and end in Seattle on September 21 are being formulated and will be announced in early summer. Advance registration forms and transportation information will be distributed in August.

Abstracts

The deadline for abstracts is July 15, 1981, and they must be submitted in the standard AGU (see page 20 of January 13 *Eos*) format.

Abstracts should be typed single-spaced with a dark ribbon so that they can be legibly reproduced by the Xerox process. Mathematical symbols may be handwritten with India ink or black ball-point pen. The text should be limited to the most important information: a clear statement of the problem, the method of solution, and the results obtained. It should not be just an expanded title, with statements such as '... will be presented' interspersed. The maximum dimensions of the abstract are 10.4 cm by 20 cm.

Authors assume responsibility for accuracy of the data submitted, and the secretary-treasurer is responsible for correct reproduction. To facilitate his job and to avoid mistakes, please put the author's name and the title of the paper on every sheet submitted.

Send the original plus two copies to Bob Bentley, Secretary-Treasurer, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, Washington 98926. He will distribute copies to the appropriate chairman.

Available as standard equipment are single 35-mm slide projectors and overhead projectors. Unless otherwise specified, 15 minutes (10 minutes for presentation and 5 minutes for discussion) will be allowed for each paper. Authors are encouraged to bring preprints of their papers for distribution to the audience. ✠

Travel Grants to IAGA and IAMAP Scientific Assemblies

Deadline for Applications: April 1

AGU has applied to the National Science Foundation for grants to assist the travel of individual U.S. scientists to the Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy, to be held in Edinburgh, Scotland, August 3–15, 1981, and the Third Scientific Assembly of the International Association of Meteorology and Atmospheric Physics, to be held in Hamburg, Germany, August 17–28, 1981. Application forms for the grants are available from

Member Programs Division
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009
(Telephone: 202/462-6903).

1980 Fall Meeting Report

About 2430 participants registered for the 1980 Fall Meeting, the largest attendance yet at a Fall Meeting; 1859 papers were presented.

The special session on the 1980 eruption of Mount St. Helens, presented by Robert L. Christiansen, and the one on the Voyager I encounter with Saturn both drew close to 1500 attendees.

Other highlights were Clyde Wahrhaftig's field trip on the Sunday before the meeting; the unofficial Fun Run, the results of which were published in the January 27th issue of *Eos;* and the section luncheons.

For whoever missed the field trip this time, there is another in the works for the 1981 Fall Meeting.

Changes and late end revised abstracts are printed below.

Papers Not Presented

GP13, R. T. Marrill and G. M. Smith.
H39, C. A. Quesada-Mateo; H80, M. Dattinger; H100, C. K. Liu.
M14, C. L. Korb et al.; M15, E. J. Hurley et al.; M25, G. L. Kok et al.; M36, J. G. Norton; M51, T. Hinkley; M56A, M. M. Millan et al.; M81, R. L. Lehman; M64, E. Sauer; M65, C. E. Buell and R. C. Bundgaard; M67, C. McDonald et al.; M101, R. G. Fowler; M102, E. P. Krider et al.; M113, J. M. Rosen and D. J. Hofmann.
O6, B. R. Pearce and A. C. Humphreys; O28, T. C. Moore, Jr., et al.; O30, A. L. Gordon; O35, A. D. Socci and M. A. Sommer, II; O41, Y. Hsueh and L. Vensent; O53, R. O. R. Y. Thompson and T. J. Golding; O88, R. E. Wall; O99, S. Aranuvachapun; O118, M. Styrt and H. D. Hollend; O128, K. Wyrtki; O173, K. M. Kuivila and J. W. Murray; O195, S. Mecintyre and J. M. Melack; O247, M. Reilray, Jr., et al.; O248, C. Frankignoul; O258, S. D. Chapnick et al.; O281, J. J. Tsai and J. R. Pronl.
P12, G. Schubert and J. M. Straus; P34, M. A. Lange.
S15, J. Regan and H. Kanamori; S19, T. H. Heaton; S28, S. A. Alsinawi; S69, Y. Yu-Rong; S70, C. Zu-huang; S73, C. Shuhai, et al.; S91, M. Takemura and J. Koyama; S133, D. W. Rivers and Z. A. Der; S184, C. A. Salvado; S198, B. Chouet; S207, J. Mwenitumbo and H. H. Schloessin.
SA2, K. V. Chance and W. A. Traub; SA26, L. E. Wharton and N. W. Spencer; SA37, M. R. Torr et al.; SA42, R. O. Olsen; SA75, R. D. Harris.
SC11, S. P. Agrewal; SC16, R. Reinhard; SC20, G. M. Mason and H. Weiss.
SM64, P. A. Isenberg; SM68, U. S. Inan and T. F. Bell; SM97, H. Belsiger et al.; SM99, A. Ghielmetti et al.; SM117, T. Sato and A. Hasegawa; SM153, L. C. Lee et al.; SM178, R. J. Walker; SM212, A. F. Cheng and B. Altner.
SS7, M. Heinemann; SS27, W. K. H. Schmidt et al.
T11, C. Schubert; T33, T. J. Ahrens; T57, G. T. Nixon.
V51, J. Ach and S. E. DeLong; V59, S. Self and M. R. Rampino; V89, M. R. Perfit et al.; V124, J. V. Smith.

Postdeadline Abstracts

G 16A

VARIABILITY OF GEOID AND OCEAN SURFACE SPECTRA FROM SEASAT-1 ALTIMETER DATA

R.D. Brown (Phoenix Corporation, 1700 Old Meadow Road, McLean, VA 22102)
B.D. Kahn (Goddard Space Flight Center, Greenbelt, MD 20771)
R.S. [illegible] (Phoenix Corporation, 1700 Old Meadow Road, McLean, VA 22102)

[illegible]

... tidal and mesoscale ocean phenomena. These results have implications for planning of geodynamics and ocean observing satellite missions.

H 40A

COLUMBIA RIVER WATER WITHDRAWAL STUDY

Jeffrey R. Bradley (Hydrology Section, Portland District, Corps of Engineers)
[illegible]

The Columbia River is a complex and heavily utilized resource ... [illegible]

H 46A (INVITED PAPER)

EROSION OF SEDIMENTS RELEASED BY THE 1980 ERUPTIONS OF MT. ST. HELENS

Andre Lehre, Thomas Dunne, Lee Fairchild, Brian Collins (Dept. of Geological Sciences, University of Washington, Seattle, WA 98195)

The 1980 eruptions of Mt. St. Helens emplaced ... [illegible]

H 46B (INVITED PAPER)

FIELD EVIDENCE FOR THE DYNAMICS OF THE TOUTLE RIVER MUDFLOWS, MAY 18, 1980

Mark Wigmosta, Lee H. Fairchild, J. Duegan Smith, Thomas Dunne, Peter Flanagan (Dept. of Geological Sciences, University of Washington, Seattle, WA 98195)

Superelevation of mudflows around 13 bends in the North and South Forks of the Toutle River ... [illegible] ... by these last two processes allow calculation of the volume of ash removed under a variety of gradients and a range of ash texture during light spring rains. The measurements also suggest the distribution and magnitude of erosional processes during future wet seasons.

H 51A

ANALYSIS OF TRACE GASES FROM MT. ST. HELENS VOLCANIC ASH

R. A. Rasmussen (Oregon Graduate Center, Beaverton, Oregon 97006)
M. A. K. Khalil, S. A. Penkett, and T. Cassdevalle

Analyses of the volatile materials released at room temperature from Mt. St. Helens volcanic ash have consistently shown for a wide variety of samples, representing eruptive events both prior to and after the May 18 eruption, that the following trace gases are present: CO_2, CO, CS_2, COS, SO_2, CH_3Cl, CH_3Br, CH_3I, $CHCl_3$ and CCl_4. In addition, a variety of more complex organic compounds have been identified: ethyl chloride, acetone, dibromochloromethane, dichlorobromomethane, and a wide spectrum of unidentified halocarbons and hydrocarbons. The species detected are not believed to be due to contamination related to collection or handling procedures. Analysis of the complex array of gases measured in the headspace above the ash samples suggests that many of the species do not represent a simple desorption of the previously adsorbed material. Rather, comparison of results of samples subjected to thermal studies versus photolysis indicates that many of the species measured (i.e., CO_2, CO, CH_3Cl) are being produced by UV irradiation breaking down higher molecular weight compounds adsorbed on the ash. The ash is a highly adsorptive material and has been observed to readily adsorb from the air both low molecular weight materials like CH_3CCl_3 and high molecular weight compounds like polynuclear aromatics, i.e., naphthalene, anthracene, etc. Further work is in progress to explain the observed phenomena and will be reported at the meeting.

H 56A

SPECTROSCOPIC MEASUREMENT OF SO_2 VOLCANIC EMISSIONS

Millan, Millan M., (Barringer Research Ltd., Toronto, Ontario Canada)
Galleni, Allon J. and Poneki, Fosed Atmospheric Environment Service, Environment Canada, Toronto, Ont. Canada
(Sponsor: Thomas Casadevall)

Correlation Spectrometer (COSPEC) remote sensors have been now routinely used to monitor SO_2 emissions from volcanoes and have played an important role in the forecast of Mt. St. Helena activity after the May 18th eruption. The instrumental operating characteristics will be briefly described emphasizing the atmospheric effects on the SO_2 measurements. Experimental observations of the Mt. St. Helens, May 18th, SO_2 cloud over Southern Ontario will also be presented.

H 95A

DOPPLER SPECTRA OF LIGHTNING ECHOES WITH A VERTICALLY POINTING RADAR

Don MacGorman (CIMMS, University of Oklahoma, Norman, OK 73019)
Dusan S. Zrnic', (NOAA, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069)
V. David Rust, (NOAA, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069)
William L. Taylor, (NOAA, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069)

Digital time series data at 16 heights through two storms were collected with a 10-cm Doppler radar at vertical incidence. On several occasions during data collection, lightning echoes were observed as increased reflectivity on an oscilloscope display. Simultaneously, lightning signals from nearby electric field change antennas were recorded on an analog recorder together with the radar echoes. Reflectivity, mean velocity and Doppler spectra were analyzed for time series before, during and after lightning discharges. Spectra from locations where lightning occurred show peaks due to the motion of lightning channel as it follows the air speed. These peaks are considerably narrower than the ones due to precipitation. In some instances, the channel extends over a kilometer in depth. Besides providing a means of measuring the vertical air velocity that can then be used in estimates of dropsize distribution, the lightning spectra provide a convenient means to estimate the radar cross section of the channel. The relationship between lightning occurrence and subsequent changes in the reflectivity and Doppler spectrum width is also examined.

H 119A

AN EFFECT OF THE CIRCULAR POLARIZATION ON THE LIGHTNING DETECTION

V. Mazur (Electrical Engr. Dept., University of Oklahoma, Norman, OK 73019)
G. Walker (Electrical Engr. Dept., University of Oklahoma, Norman, OK 73019)

The effectiveness of detecting lightning with linearly polarized (LP) radar is a function of the frequency band. At L-band (1300 MHz) echoes from the heavy precipitation regions often mask a big percentage of lightning events. To reduce this problem, the circular polarization has been proposed. The effect of the circularly polarized (CP) radar on the lightning detection is investigated both theoretically and experimentally (radar FPS-8, λ=23 cm). The theoretical analysis is based on a rigorous solution of the wave equation for a dielectric cylinder of infinite length and oblique angle of incidence. Four series of observations of 4–5 minutes obtained while switching polarization (LP and CP) show an effective reduction of the precipitation echo relative to the lightning echoes. As a result, the total number of recognizable lightning echoes is increased, especially outside of a heavy precipitation core region.

O 63A (INVITED PAPER)

POLLUTANT RESPONSES IN MARINE ANIMALS (PRIMA)

R.F. Lee (Skidaway Institute of Oceanography Savannah, Georgia 31406)
(Sponsor: Rodger Baier)

The objective of PRIMA is to define morphological, biochemical, and physiological indices that can be used in diagnostic tools to detect significant chemical impairment in marine animals. The approach of PRIMA is to assess responses of selected marine animals to representative pollutants. The nature of physiological systems demands that the various processes be studied in an integrated, combined effort to understand how pollutants affect marine animals. Thus, our interdisciplinary approach is designed to define important physiological processes in variation in chemical and physical conditions. The biological processes and effects studied include accumulation and release kinetics, biotransformation (detoxification and toxicogenic), corticosteroid and related stress responses, ascorbic acid metabolism, histopathology, histochemistry, and immune competence (defense mechanisms). Techniques to measure pollutant effects are being developed and standardized under laboratory conditions and then will be used to examine stressed and unstressed field populations.

Studies of bioaccumulation and depuration of pollutants by the selected animals were carried out or are in progress. Biotransformation studies have centered around cytochrome P-450-dependent mixed function oxygenase (MFO) systems. Changes in the characteristics of MFO systems, including induction and/or altered spectral properties of cytochrome P-450, were observed in microsomes of clams, crabs, fish and worms exposed to the pollutants. Metabolic products of several pollutants formed by these species were identified. MFO systems and changes with normal variables (such as sex and season) that affect cytochrome P-450 are being characterized.

O 63B (INVITED PAPER)

ENEWETAK TOWER EXPERIMENT: SEA-AIR EXCHANGE PROGRAM (SEAREX)

R. E. Gagosian and O. C. Zafiriou (Chemistry Department, Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543 USA)
R. A. Duce (Graduate School of Oceanography, University of Rhode Island, Kingston, R.I. 02881 USA)
J. M. Prospero (Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Fla. 33149 USA)

One of the main objectives of the SEAREX Program has been to determine the sources and fluxes of atmospheric particulate matter found in the oceans. One approach we have taken in accomplishing this objective has been to collect atmospheric particulate matter from 20 m towers in the northern and southern trade wind regime and to analyze this material for organic and inorganic components which provide source marker information for terrestrial, marine or atmospheric reaction inputs. The first such experiment was conducted in the northeast trade winds on Enewetak Island, Enewetak Atoll, Marshall Islands from April to August, 1979.

The results of this investigation revealed a large number of continentally-derived particulate organic compounds. Over the five month period, a factor of 3-7 decrease was found for the organic compounds indicative of terrestrial origin (C_{22}-C_{36} odd chain n-alkanes, C_{20}-C_{32} even chain fatty alcohols and fatty acid esters and acids). Ratios of Fe/Al, Sc/Al and Mn/Al were found to be very similar to mean crustal ratios. The atmospheric aluminum concentration (used as an indicator of continental dust) decreased by a factor of 50 over the course of the experiment.

Meteorological and climatological studies show that large amounts of dust from China were probably transported during April-May into the Enewetak area by a very strong westerly flow of wind at 700 mb followed by a subsidence into the trade winds east of Enewetak.

O 63C (INVITED PAPER)

The Vertex Program

John H. Martin (Moss Landing Marine Laboratories, Moss Landing, California 95039)

The Vertex program is made up of a small group of scientists interested in studying the vertical transport and exchange of materials in oceanic water columns. One of the aims of the program is to learn more about how the "sending particle" transport system works; i.e., by studying the primary particle producers (phytoplankton), the large, fast-sinking particle producers (zooplankton) and the particle decomposers (microorganisms), in relation to the environments these organisms inhabit. Studies on the transport system are coupled with flux measurements made with particle interceptor traps set throughout the upper 2000 m of water column. Elements and compounds that are being measured in water and in trapped particulates include C, N, P, trace elements, organic compounds (lipids, organic N, pollutants and biogenic hydrocarbons), natural series radionuclides and transuranics. The various components and how they interrelate will be described. Initial results from the first cruise will be presented, along with plans for future field efforts.

O 65D (INVITED PAPER)

MANOP: *IN SITU* STUDIES OF ELEMENTAL FLUXES AT THE DEEP-SEA FLOOR

G. Ross Heath (School of Oceanography, Oregon State University, Corvallis, OR 97331)
Ray F. Weiss (Scripps Institution of Oceanography, University of California, San Diego, CA 92093)

To assess factors governing the formation and transition-metal geochemistry of deep-sea ferromanganese nodules, MANOP is measuring nutrient and elemental fluxes at five Pacific sites encompassing the major pelagic sediment types. Fluxes being measured include dissolved species in bottom and pore waters, vertically settling particulates, and deposition in sediments and nodules. The innovative aspects of the program are the tight coordination of the various measurements, and the use of a sophisticated Bottom Lander to carry out experiments at the sea floor. The Lander's capability to add or remove aliquots or measure properties in three "bell jars" on the bottom can be controlled via an acoustic link to the surface, or via preprogrammed instructions stored in an integral microprocessor system. At the end of an experiment, the Lander collects the sediment beneath each chamber or "bell jar", jettisons a ballast plate, and floats to the surface.

O 25A (INVITED PAPER)

Manganese Cycling in NE Pacific Equatorial Waters

John H. Martin (Moss Landing Marine Laboratories, Moss Landing, California 95039)
George A. Knauer (Moss Landing Marine Laboratories, Moss Landing, California 95039)

Particles trapped at depths of 120, 275, 625 and 900 m in NE Pacific equatorial waters (2000 km offshore) were analyzed for their Mn content. Observed fluxes, resulting from these data, increased steadily with depth, from 300 at 125 m, to 385 ug Mn m^{-2} 1000 yr^{-1} at 900 m. The continuous gain in Mn flux occurred in spite of large total particulate and organic C flux decreases occurring near the surface (from 7.1; 2.3 at 125 m to 2.4; 0.1 g m^{-2} 1000 yr^{-1} at 275 m for total dry particulates and organic C, respectively). The marked reduction in organic C amounts resulted in an elevation of water MnC ratios from 6.8 X 10^{-3} at 125 m, to 6.2 X 10^{-3} at 175 m.

Using a model based on the last near-surface Mn flux measurement, a bottom Mn flux of 460 ug cm^{-2} 1000 yr^{-1} was estimated. Of this Mn, 95% was scavenged from the water column; model-predicted dissolved Mn removal rates were highest near the surface (-8.8 ug l^{-1} yr^{-1} at 100 m) and lowest at depth (-0.1 ug l^{-1} yr^{-1} at 4000 m). The measured and estimated Mn transport rates indicate that a major portion of the Mn excess found in open ocean sediments is derived from near-surface waters. The input sources appears to be surface current advection of dissolved Mn originally released via continental weathering processes.

O 25A (INVITED PAPER)

STUDIES OF METHANE OXIDATION IN ANOXIC MARINE SEDIMENTS

W.S. Reeburgh (Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701)

Anaerobic methane oxidation has been suggested as a process occurring in anoxic marine sediments. The process appears to be a general feature of marine sediments and consumes essentially all of the upward methane flux. Slope changes in the depth distributions of methane, carbon dioxide and sulfate suggest that the reaction occurs in a subsurface zone. A minimum in depth distributions of the stable carbon isotope ratio to carbon dioxide, located at the depth of the above slope changes, suggests it to be caused by in situ injection of isotopically light, methane derived carbon dioxide.

This presentation describes the methods used and gives results of tracer experiments on anaerobic methane oxidation. These experiments involved addition of $^{14}CH_4$ solutions to undisturbed sediment cores from Skan Bay and Chesapeake Bay. The results indicate that anaerobic methane oxidation does occur and that the rates and zone depth distributions are in accord with model predictions.

O 25B (INVITED PAPER)

ASSOCIATION OF THE METHANE SEDIMENT-WATER FLUX AND MICROBIAL ACETATE TURNOVER IN ORGANIC-RICH MARINE SEDIMENTS

C. S. Martens (Curriculum in Marine Sciences, University of North Carolina, Chapel Hill, N.C. 27514 and Institute of Marine Sciences, UNC, Morehead City, NC 28557)
S. J. Sansone
(Sponsor: Larry B. Benninger)

The measured methane flux across the sediment-water interface in Cape Lookout Bight, NC ranges seasonally from 30-2600 umole m^{-2} h^{-1} over a temperature range of 5-17°C. Methane and radon-222 sediment gas distribution studies suggest that this flux is largely supported by methane production in the 0-35 cm deep zone underlying sulfate reducing sediments. Apparent microbial production of methane from acetate in the top 5 cm of this core seasonally correlates with the methane flux and ranges from 50-600 umole l^{-1} h^{-1}. These apparent rates are based on measured sediment concentration measurements and in vitro labelled acetate incubation experiments. Significant methane production from acetate occurs only in sulfate depleted sediments; a maximum rate is observed at 14-19 cm depth during July.

O 25C

INSTRUMENTAL DETERMINATION OF MICROBIAL TRANSFORMATION RATES IN THE MARINE WATER COLUMN

Craig D. Taylor (Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543)
Robert R. Guillard and John J. Molongoski

Instrumentation has been developed that will permit the time-series measurement of microbially mediated chemical transformations directly in situ. [illegible]

O 26A (INVITED PAPER)

CRITERIA OF MICROBIAL ACTIVITIES IN NATURE

Kenneth H. Nealson, Bradley M. Tebo, and Reinhardt A. Rosson (Scripps Institution of Oceanography, La Jolla, CA 92093)

Several criteria are commonly used to implicate microbes as causative agents in geochemical processes: (1) the presence of organisms with the potential to perform a certain reaction, (2) the presence of distinctive structures that are deposited as a result of microbial activities, and (3) measurements of activities in situ in the presence and absence of microbial poisons or inhibitors. However, caution must be taken in such studies, both in experimental design and interpretation of the data. [illegible]

While any one of the criteria listed above might be considered inadequate, when applied together, and with the appropriate cautions, a convincing case for microbial involvement can be made. All three criteria have been used in our studies of manganese oxidation in Saanich Inlet, B.C. and the data indicate that bacterial catalysis is a major factor in the oxidation of manganese.

P 26A

POSSIBLE CLIMATIC EFFECTS OF A MARTIAN PALEOMAGNETIC FIELD

Bruce M. Cordell (Dept. of Physics, California State College, Bakersfield, CA 93309)

A new mechanism for climatic change on Mars involving interactions between the atmosphere and a hypothesized ancient planetary magnetic field is discussed. [illegible]

S 80A

SHORT AND INTERMEDIATE TERM RADON ANOMALIES AS POSSIBLE EARTHQUAKE PRECURSORS

E. Hauksson (Dept. Geol. Sci. and Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964)

The properties of 70 radon anomalies reported as precursors to earthquakes in the U.S.S.R., U.S., China, Japan, and Iceland are analyzed. [illegible] ... suggest that the preparation zone of the earthquake where precursors occur, expands with time away from the prospective rupture zone. A network of several radon stations spaced 20-50 km apart and located anywhere from one up to ten rupture dimensions away from the future epicenter, appears to be well suited to catch precursory radon anomalies associated with large earthquakes.

S 91A

EARTHQUAKE SOURCE PARAMETERS AND SCALING LAWS

C. H. Scholz (Dept. Geol. Sci. and Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964)

We approximate a dynamic theory of rupture in order to study the relationships between the static and dynamic seismic source parameters and their scaling laws. For small earthquakes, modelled as bounded circular ruptures, static stress drop is proportional to dynamic stress drop and is independent of rupture dimensions. For large events, modelled as rectangular ruptures with one edge at the free surface, mean slip is proportional to rupture length and static stress drop is proportional to dynamic stress drop and to the aspect ratio of the rupture. The observations show that dynamic stress drop is almost a constant between 1 and 10 bars for larger interplate earthquakes, and mean slip and static stress drop increase linearly with fault length and aspect ratio, respectively. The theory also predicts the observed surface slip distribution observed on faults, and it is shown that all the static and dynamic source parameters can be derived from these observations. The assumption of constant static stress drop for large earthquakes is incorrect and leads to serious errors, as in the M_s magnitude scale, which systematically underestimates the moments for the largest earthquakes.

S 116A (INVITED PAPER)

ABCD METHOD FOR STATICS COMPUTATION

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Costain, J. K., Regional Geophysics Laboratory, Va. Polytechnic Institute and State University, Blacksburg, VA 24061

The ABCD statics computation method (Coruh, 1975) is based on the use of seismic refraction arrivals at adjacent receiver locations. The time difference of the refraction arrivals between two adjacent receivers from a source point is due to travel path difference on the refractor and the static difference between receiver points. Time difference of the time differences of refraction arrivals at the adjacent receivers from points in opposite directions can be determined. The static difference between two adjacent receiver points requires determination of two terms. The first term is the time difference of the time differences of the refraction arrivals which can be easily computed from the first breaks on the records. The second term is directly proportional to the elevation difference between the receivers points and tangent of the critical angle, and inversely proportional to the velocity of the refractor.

The algebraic sum of the static differences for all adjacent pairs will show relative static variation along the profile. The relative statics curve can be tied to actual statics at two or more points to obtain the actual static correction function.

Using conventional reflection data, the ABCD statics can be computed from the first breaks. In rolling statics, the ABCD method can be applied more than once on the same data. The method can be also applied on data on which field statics have already been applied.

S 116B (INVITED PAPER)

EFFECT OF AUTOMATIC GAIN CONTROL BEFORE CROSS-CORRELATION ON RESOLUTION OF WIDE-BAND VIBROSEIS DATA

Costain, J. K., Regional Geophysics Laboratory, Va. Polytechnic Institute and State University, Blacksburg, VA 24061
Coruh, C., Regional Geophysics Laboratory, Va. Polytechnic Institute and State University, Blacksburg, VA 24061

Multifold (48-fold) reflection data were acquired during 1980 on the Atlantic Coastal Plain near Portsmouth, VA, using the VP16SU VIBROSEIS/MDT-10 system and Chebychev geophone arrays. Thickness of Cretaceous and younger sediments here is approximately 550 m. Sediments are relatively unconsolidated sands and clays and rest on unmetamorphosed granite basement. Single vibrator (Y-1100) sweeps of frequency content 100 Hz to 20 Hz were used in an attempt to obtain data of relatively high resolution. It was found that application of digital automatic gain control to the field traces before crosscorrelation with the pilot sweep resulted in a remarkable improvement in overall resolution and data quality of reflections originating from within the sedimentary section. Spectral analysis of traces before and after application of AGC shows good correlation but some whitening. The length of the AGC window determines the degree of whitening.

S 199A

SIMULATED REFLECTED PHASES FROM ROUGH BOUNDARIES

Pat Scott, Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125
Donald V. Helmberger (same)

The scattering of high frequency waves by 3-dimensional curved surfaces is investigated by numerically evaluating the Kirchhoff integral representation of the scalar wave equation. The Kirchhoff response is calculated by discretizing the surface of a hemisphere, specifying simple point sources on each element of the surface, and summing the contributions from the elements. The results of our method are compared to those of an asymptotic, first order approximation of the analytical solution of SH waves impinging on a rigid sphere. The agreement between the results of the two methods is excellent for source and receiver distances which are large compared to the radius of the sphere. When the source and receiver are at the same place, we can demonstrate analytically the equivalence of the two solutions. We also calculate responses caused by scattering from a bump or a spherical surface. The defocusing effects from such bumps can be significant. We find that these effects are a function of the frequency content of the source pulse.

SA 53A

THE GROWTH AND DECAY OF HF-INDUCED PLASMA WAVES IN THE IONOSPHERE

Frank T. Djuth
Suman Ganguly (both at: Dept. of Space Physics and Astronomy, Rice University, Houston, TX 77001).

The recently completed HF (3-12 MHz) ionospheric heating facility near Arecibo Observatory has been used to study the temporal development of parametrically enhanced plasma waves in the F region. Experimentally, the Arecibo 430 MHz radar was used to measure the growth rate of HF-induced plasma line enhancements over a time interval starting at the turn-on time of the HF electric field in the plasma and extending over time scales of many milliseconds. Plasma line rise times of several milliseconds were observed in the data. There was no evidence in support of rapid (≤10 usec) plasma wave growth rates. Thus, the presence of large amplitude plasma waves generated immediately at the onset of the

Additional And Revised Abstracts

Geomagnetism and Paleomagnetism

Oceanography

Planetology

cannot be explained by celestial mechanics effects alone. It has been suggested that electromagnetic effects are of considerable importance. Such effects are of two types; those working today, and those which were at work at cosmogonic times when the ring system was formed.

The rapidly varying spoke structure is of the first type. According to a paper by Hill and Mendis (1980), the spokes are formed by micron-sized electrically charged grains levitated by electrostatic repulsion from the large-sized bodies in the ring, and concentrated by electric currents. The same paper also suggests a theory of the braided structure of the F-ring.

There is good reason to believe that the basic structure of the Saturnian rings derives from cosmogonic times. If electromagnetic forces are active today there is every reason to believe that they were also active at cosmogonic times (Alfvén & Arrhenius, 1976). These mechanisms are discussed briefly. A detailed analysis of the Voyager results is likely to discriminate between different cosmogonic theories.

Hill, J.R. & Mendis, D.A. (1980) On the braids and spokes in the Saturnian ring system (submitted to Astrophys. & Space Sci.).

Alfvén, H. and Arrhenius, G., 1976, Evolution of the Solar System, NASA SP-345.

Seismology

ANISOTROPIC SYNTHETIC-SEISMOGRAMS IN INFLATED HDR RESERVOIRS

Stuart Crampin
David C. Booth (both at Institute of Geological Sciences, Murchison House, West Mains Road, Edinburgh, EH9-3LA, Scotland, U.K.)

Correct interpretation of seismograms of acoustic events in hydrofractured reservoirs appears to be the only way to resolve details of the crack geometry and monitor crack growth. Hydrofracturing at the HDR experiment at Los Alamos, at one stage, appears to have opened a classic system of large parallel vertical cracks enclosing a slab of small aspect-ratio which subsequent cooling made effectively anisotropic by opening cracks perpendicular to the faces of the major cracks. Such effective anisotropy can be modelled by an elastic tensor which displays the same velocity (and attenuation) variations as the cracked solid. Synthetic seismograms through such an inflated structure are calculated by modifying the reflectivity technique to accept anisotropic layers.

At the particular stage of the LASL HDR experiment we are modelling downwell three-component geophones record seismograms showing many combinations of two basic seismograms with several unusual features. Our (very preliminary) modelling produces synthetic seismograms with these same features ...

... magnitude above which the earthquake is considered as strong. Three bursts of aftershocks occurred after these thresholds were established and were followed by a strong earthquake.

Possible model of premonitory clustering is an expanding crack with dynamic friction depending on the slip-rate θ and dynamic cohesion depending on the velocity of the crack expansion ℓ. Abnormal clusters appear in such model under following conditions: shear stress is large; friction rapidly increases with θ; cohesion rapidly decreases with ℓ; local minima of friction and/or local concentrations of shear stress are present.

SPR: Aeronomy

SIMULTANEOUS MEASUREMENTS OF ION DRIFTS AND NEUTRAL WINDS USING INCOHERENT SCATTER AND FABRY-PEROT INTERFEROMETER TECHNIQUES

O. Behnke (NAIC, Arecibo Puerto Rico 00612)
R. G. Burnside and F. A. Herrero (Dept. of Physics, University of Puerto Rico, Rio Piedras, P. R. 00931)

Simultaneous measurements of F-region ion drifts and neutral winds have been carried out successfully for the first time. Ion drifts were measured with the incoherent scatter radar using a beamswing technique by which the ion velocity is decomposed into components parallel and perpendicular to the magnetic field lines. Neutral winds were measured with the Fabry-Perot interferometer measuring the Doppler shifted 6300Å emission line, using a similar beamswing technique to obtain both meridional and zonal wind components. A comparison of the zonal ion drift with the zonal neutral wind shows that both ions and neutrals move together in the east-west direction. Since east-west ion motion is the result of E×B drift, our results suggest that this ion drift is due almost entirely to polarization electric fields set up by the zonal neutral wind. It is shown that this is a very important mechanism for Arecibo. A comparison of ion drifts along the field lines with the meridional neutral wind allows a direct measurement of the diffusion velocity. It is shown that although standard methods of estimating the diffusion velocity usually yield reasonable results, there are some exceptions.

SPR: Magnetospheric Physics

CAN COLLISIONS INHIBIT FIELD DE-CONNECTION?

A. Sciaccaluga (Department of Physics, University of California, San Diego, La Jolla, CA 92093)
(Sponsor: Eldon Whipple)

...

ELECTRIC FIELDS

N. R. Thomson (Department of Physics, University of California, San Diego, La Jolla, CA 92093)
(Sponsor: Eldon Whipple)

... require driving fields. As a specific example finite length effect on the Kelvin Helmholtz instability is analysed using the small Larmor ...

AURORAL ARCS: BOUNDARIES BETWEEN MAGNETIC FLUX TUBES

G. Atkinson (National Research Council of Canada, Ottawa, Ontario K1A 0R6)

A new theory of the macroscopic conditions for auroral arcs to form is proposed. It is suggested that arcs may form where the topology of the magnetic field ... magnetized plasmas to be adjacent, or where the time history of the flux has produced two adjacent magnetized plasmas. Under these conditions an arc will form at the boundary between the two plasmas if a sufficiently intense upward-directed current is required by the difference in magnetic field across the boundary. The boundary is a tangential discontinuity ... arc is therefore ... between sunward and ... evening side, at boundaries between open and closed field lines ... polar cap sun-aligned arcs, and at boundaries between plasmas which have merged on the dayside or reconnected on the nightside in different impulsive events. The last accounts for parallel arcs within the oval and for arcs occurring near the throat of active lines.

SS: Solar and Interplanetary Physics

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Geodesy and Gravity

1905 Artificial satellite techniques
A COMPARATIVE ANALYSIS OF GPS RANGE, DOPPLER AND INTERFEROMETRIC OBSERVATIONS FOR GEODETIC POSITIONING

Patrick Fell (Naval Surface Weapons Center, Dahlgren, Virginia 22448)

Geodetic positioning accuracies obtained from range, integrated Doppler and double differenced interferometric phase observations from a constellation of twenty-four Global Positioning System satellites are presented. It is demonstrated that GPS range and Doppler observations will provide sufficient accuracy for the estimation of geodetic coordinates. However the instability of the receiver atomic oscillator will limit the usefulness of these observations in providing rapid first-order baseline determination. Interferometric phase measurements twice differenced to eliminate clock errors appear as an alternate procedure for providing such accuracies.
Bulletin Geodesique, Vol. 54, No. 4

1906 Artificial satellite techniques
ACCURACY OF MEAN EARTH ELLIPSOID BASED ON DOPPLER, LASER AND ALTIMETER OBSERVATIONS

Richard J. Anderle (Naval Surface Weapons Center, Dahlgren, Virginia 22448)

The error in the mean earth ellipsoid computed on the basis of Doppler or laser observations of artificial earth satellites or radar altimeter observations of the ocean surface from a satellite depends upon instrument precision, on uncertainties in the specification of the earth's gravity field at both long and short wave lengths, on uncertainties in the origin of the coordinate system, on modelling errors in ionospheric (except laser) and tropospheric refraction, and, for altimetry, on oceanographic effects. The magnitude of the uncertainty in the computed ellipsoid will vary depending on the size of these errors and on the number and distribution of observation stations. Review of computations based on various data sets indicates that differences in the computed ellipsoids are consistent with those expected due to the various error sources and that the best fitting ellipsoid has a semi-major axis of 6378136±2 m.
Bulletin Geodesique, Vol. 54, No. 4

Izvestiya Atmospheric and Oceanic Physics
Volume 15, Number 12, 1979

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CRITICS AND BIBLIOGRAPHY

CHRONICLE

1905 Artificial satellite techniques
USING THE GLOBAL POSITIONING SYSTEM (GPS) FOR GEODETIC POSITIONING
John Bossler & Clyde Goad (National Geodetic Survey, NOS, NOAA, Rockville, Maryland 20852)

The development of relatively inexpensive satellite receivers in the early 1970's has resulted in cost-effective applications of satellites for a variety of geodetic surveying needs. Currently achievable accuracies range from 10 to 20 centimeters. The NAVSTAR Global Positioning System, now under development by the Department of Defense, incorporates advanced technology which has the potential capability of revolutionizing satellite geodesy.

Several concepts for utilizing GPS signals are briefly reviewed, and another concept, called the reconstructed carrier phase method, is described in some detail. This concept is being pursued by the Defense Mapping Agency, National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. These agencies have numerous requirements for accurate positioning. Several prototype receivers are planned to be available for testing in mid-1982. These receivers should be highly portable, consume little power, and obtain baseline accuracies of several centimeters in several hours of observation time. However, water vapor radiometers will be needed in order to achieve the full accuracy. Initial simulation results utilizing the reconstructed carrier phase method are included.
Bulletin Geodesique, Vol. 54, No. 1

1920 Geometric observations and methods
DEFORMATIONS OF GEODETIC NETWORKS IN GRAVITY INVARIANT AND POTENTIAL INVARIANT REPRESENTATIONS
Edward Osada (Inst. of Geodesy & Applied Math., ul. Grunwaldzka 53, 50-357 Wroclaw, Poland)

The analysis of deformations and reductions of the geodetic networks in general gravity invariant and potential invariant representations of the actual gravity field of the Earth by normal (theoretical) gravity field has been presented.

It has been shown that the linearized formulae of the scale factor and linearized formulae of the transformed azimuth and zenith distance indicate the conformal character of transformation of three-dimensional networks in isozenithal-type of gravity invariant representation. In isozenithal type of gravity invariant and potential invariant representation the two-dimensional (horizontal) networks are transformed conformally. In isoparametric cases of gravity invariant and potential invariant representations the two-dimensional networks are transformed nonconformally with respect to the scale and angles, but nonconformally.
Bulletin Geodesique, Vol. 54, No. 4

1929 Geometric observations and methods
SECOND ORDER DESIGN OF A FREE DISTANCE NETWORK, CONSIDERING DIFFERENT TYPES OF CRITERION MATRICES
C. Schmitt (Geodetic Inst., Univ. Karlsruhe (TH), Englerstrasse 7, D-7500 Karlsruhe, W. Germany)

1980 Instruments and techniques
A FILL-IN STORAGE TECHNIQUE FOR GEODETIC NORMAL EQUATIONS
P.A. Cross (Dept. of Land Surveying, North East London Polytechnic, London E17 4JB)

A minimum fill-in scheme, published by Yale University and not previously discussed in the geodetic literature, has been tested on four typical triangulation networks. Its computer storage requirement has been compared with that of the profile method using Snay's station reordering algorithm. Tests have been carried out for terrestrial and mixed terrestrial/satellite networks.

The conclusion is that the fill-in scheme is a viable method for geodetic networks and, in some cases, it needs less computer storage than the profile method.
Bulletin Geodesique, Vol. 54, No. 4

1990 Geodesy instruments and techniques
POSSIBLE TILT PHENOMENA OBSERVED AS WATER LEVEL ANOMALIES ALONG THE LOS ANGELES AQUEDUCT
Peter C. Leary, Peter E. Malin, Richard A. Stevlis, and Thomas L. Henyey (Department of Geological Sciences, University of Southern California, Los Angeles, California 90007)

Water levels in the Los Angeles Aqueduct in southern California fluctuate in a manner that are not easily attributable to normal aqueduct operations. Simple hydraulics suggests that large scale earth tilt can register as water level anomalies with a sensitivity of about .01 ft/microradian. Two aqueduct anomalies which coincide spatially and temporally with independently observed deformational phenomena are used to explore this suggestion.
Geophys. Res. Lett., Paper 1L0128

Hydrology

3115 Evaporation
ESTIMATING EVAPOTRANSPIRATION FROM THE SONOITA CREEK WATER SHED NEAR PATAGONIA ARIZONA
J. Ben-Asher (The Jacob Blaustein Institute for Desert Research and Department of Biology, Ben-Gurion University of the Negev, Beer Sheva, Israel).

In a study that was proposed to evaluate the water balance of the Sonoita Creek watershed near Tucson, Arizona, monthly evapotranspiration was defined by Morton's ...

Meteorology

Mineralogy, Petrology, and Crystal Chemistry

Oceanography

4740 Marine geological processes
MAINTENANCE OF THE SHOREFACE BY WAVE ORBITAL CURRENTS AND MEAN FLOW: OBSERVATIONS FROM THE LONG ISLAND COAST
A. W. Niedoroda (Woodward Clyde Consultants) and D. J. P. Swift

... "northeaster" storm, a downwelling coastal jet developed, with 60 cm sec^{-1} maximum currents. The calculations show that if this flow had been combined with the intense wave regime of the succeeding several days, sediment would have been entrained across the lower as well as the upper shore face. Movement would have been offshore and alongshore. Such storm transport is believed to be typical of the more intense winter storms, and responsible for the erosional shoreface retreat that has caused up to a kilometer of shoreline retreat on the Long Island coast in the last century. (Shoreface, wave-orbital currents, wind-driven currents, sand transport).
Geophys. Res. Lett., Paper 1L0177

4750 Physical properties of seawater
THE INFLUENCE OF OPTICAL WATER TYPE ON THE HEATING RATE OF A CONSTANT DEPTH MIXED LAYER
J. Ronald V. Zaneveld (School of Oceanography, Oregon State University, Corvallis, OR 97331) James C. Kitchen and Hasong Pak

A simple heat budget model for a radiation-dominated mixed layer of constant depth is presented. In this model the influence of the vertical irradiance (heat flux) profile is examined by means of Jerlov's (1976) optical water type classification. It is shown that the vertical irradiance profile is important in determining the mixed layer heating rate. The heating rate varies greatly as a function of water type, mixed layer depth, and diffusivity beneath the mixed layer, ranging from 0.098°C/day for oceanic water type I with a mixed layer depth of 20 m and diffusivity beneath the mixed layer of 1.0 cm^2 sec^{-1} to 0.316°C/day for coastal type 9 with a mixed layer depth of 10 m and zero diffusivity beneath the mixed layer, a variation of more than a factor of 3. (Heat flux, irradiance, temperature, mixed layer).
J. Geophys. Res., Green, Paper 1C0171

4790 Instruments and techniques
DETECTING THE MOVEMENT OF OCEANIC FRONTS USING REGISTERED TIROS-N IMAGERY
T. R. Clark (Naval Ocean Research and Development Activity, NSTL Station, MS 39529) and P. E. LaViolette

An examination of TIROS-N AVHRR data distributed by NOAA Environmental Data Information Service (EDIS) shows that with these data one has greatly improved positioning capability in comparison with data gathered by earlier NOAA satellites. In four of five distinct TIROS-N data sets, involving earth scenes approximately 100 km square, we obtained a mean positioning error of 1.7 km with a standard deviation of 1.7 km based on 32 landmark points. The fifth data set shows discrepancies apparently resulting from erroneous EDIS data coordinates, and accurate positioning of this specific scene could not be made. In general, TIROS-N data can be reliably registered into geographic grids of various map projections by using two-dimensional, third-order polynomials. The resulting image projections can be used to monitor and to measure the movements of oceanic fronts accurately. Examples of such measurements are presented using data from the May 1979 phase of the Grand Banks Experiment. These examples include four consecutive days of registered TIROS-N imagery that show detailed southeasterly movement of horizontal frontal waves traveling at an average speed of 70 cm/sec. The accurate registration also allows precise compositing of several days' imagery. A four-day composite based on the highest daily temperature per pixel position shows that an oceanic front can often be monitored despite cloud conditions. (TIROS-N, oceanic fronts, remote sensing).
Geophys. Res. Lett., Paper 80L1734

Oceanology
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5310 Cosmic rays
THE MODULATION OF LOW ENERGY PROTON DISTRIBUTIONS BY PROPAGATING INTERPLANETARY SHOCK WAVES: A NUMERICAL SIMULATION
R. B. Decker (Applied Physics Laboratory, The Johns Hopkins University, Laurel, Md., 20810)

A numerical simulation has been developed to study the intensity in the interplanetary of ~ 0.1 to ~ 10 MeV protons of the long-lived energetic storm particle (ESP) events observed in association with the passage of flare-produced fast-mode MHD shocks. Protons are traced numerically backward in time from a given observation point (i.e., particle detector), through their adiabatic scatter-free motion along the assumed (smooth spiral IMF), and finally through the shock discontinuity to their pre-shock-interaction state. An ambient proton can undergo at most one shock encounter during which, as seen in the shock frame, the proton is accelerated by the effective "grad-B drift" along the induced electric field each time it crosses the shock. The time-reversed calculation reveals which of the observed protons interacted with the shock, where the shock interaction occurred, and by how much each interacting proton's kinetic energy was increased at the shock. Time profiles of the omnidirectional and unidirectional proton fluxes are formed from the trajectories by invoking Liouville's theorem and an ambient proton unidirectional flux ∝ $T^{-\gamma}$, where T is the kinetic energy and γ the spectral exponent. Simulation predictions are shown for different observed proton energies under various assumptions concerning the shock speed and strength, the slope of the ambient proton energy spectrum, …

5380 Shock waves
BI-DIRECTIONAL STREAMING OF SOLAR WIND ELECTRONS >80 eV: ISEE EVIDENCE FOR A CLOSED-FIELD STRUCTURE WITHIN THE DRIVER GAS OF AN INTERPLANETARY SHOCK
S. J. Bame, (P-4, MS 436, Los Alamos National Laboratory, Los Alamos, NM 87545) J. R. Asbridge, W. C. Feldman, J. T. Gosling, and R. D. Zwickl

In near time coincidence with the arrival of helium enriched plasma driving the shock wave disturbance of November 12–13, 1979, strong bi-directional streaming of solar wind electrons >~80 eV was observed with Los Alamos instrumentation on ISEE 3. The streaming persisted for many hours simultaneously parallel and anti-parallel to the interplanetary magnetic field which was directed roughly perpendicular to the sun-satellite line. This example of bi-directional streaming clearly cannot be explained by field line connection to either the earth's bow shock or the outward propagating interplanetary shock which passed ISEE-3 ~16 hours earlier. The event is best explained if the local interplanetary field was a part of either a magnetic bottle rooted at the sun or a disconnected loop propagating outward.
Geophys. Res. Lett., Paper 1L0118

5380 Solar wind interactions with moons and planets
UPSTREAM PARTICLES OBSERVED IN THE EARTH'S FORESHOCK REGION
T. E. Eastman, R. R. Anderson, L. A. Frank
Department of Physics and Astronomy, (University of Iowa, Iowa City, Iowa 52242) and G. K. Parks

Based primarily on an extensive study of fully three-dimensional plasma data, we describe the interrelationships of the upstream particles and plasma waves observed in the earth's foreshock region. The University of Iowa LEPEDEAs detect ions and electrons from 1 eV to 45 keV over all except ~ 2% of the unit sphere. Comparisons are made with high time resolution particle data obtained by the University of California (Berkeley) instruments and plasma wave data collected by the University of Iowa plasma wave instruments on the two ISEE spacecraft. The presence of ion beams or dispersed ion distributions is found to be a sufficient condition for the presence of electrostatic …

Particles and Fields—Ionosphere

Particles and Fields—Magnetosphere

5705 Bow shock waves
A STATISTICAL SURVEY OF IONS OBSERVED UPSTREAM OF THE EARTH'S BOW SHOCK: ENERGY SPECTRA, COMPOSITION, AND SPATIAL VARIATION
F. M. Ipavich (Dept. of Physics and Astronomy, University of Maryland, College Park, MD 20742) A. B. Galvin, G. Gloeckler, M. Scholer and D. Hovestadt

The characteristics of 33 diffuse particle events in the energy range from ~30 to ~130 keV/Q observed upstream of the earth's bow shock have been determined. The measurements were made with the Ultra Low Energy Charge Analyzer (ULECA) sensor of the Max-Planck Institut/University of Maryland instrument on ISEE-1. The energy spectra of these events are clearly steeper than power law and are generally well described by either an exponential or Maxwellian in energy per charge, with average e-folding values of ~20 keV/Q and ~18 keV/Q, respectively. The composition in these events is remarkably constant as a function of energy per charge and is similar (within a factor of ~2) to that of the solar wind. The particle flux is found to decay exponentially with distance from the bow shock, with an e-folding distance of ~7 R_E for H and He at 30 keV/Q. Inverse velocity dispersion was observed in each event, with an average delay time of ~40 min. between the 30 keV and 130 keV proton equilibrium intensity levels. Our measurements are consistent with a Fermi acceleration mechanism and the presence of a free escape boundary upstream of the bow shock. (Upstream particles, Fermi acceleration, composition.)
J. Geophys. Res., Blue, Paper 80A1814

5705 Bow shock waves
MEASUREMENTS OF BOW SHOCK PARTICLES FAR UPSTREAM FROM THE EARTH
K. A. Anderson (Physics Department and Space Science Laboratory, University of California, Berkeley, CA 94720)

Electrons and ions moving upstream frequently …

Planetology

6510 Atmospheres of Planets
SPECTROSCOPY OF THE CAMERON BANDS IN THE MARS AIRGLOW
R. R. Conway (LASP, Univ. of CO, Campus Box 392, Boulder, CO 80309)

Mars airglow spectra acquired by the ultraviolet spectrometer experiment of Mariner 9 were analyzed by using a high resolution synthesis. The carbon monoxide Cameron bands are the brightest features between 1800 and 2600 Å in the observation of altitudes between 88 and 180 km. The shape of these bands cannot be characterized by any single rotational temperature but is best described by temperatures of 1600 K for lower J values and 10,000 K for higher J values. The first negative bands of CO^+ are not identified in the residual spectra. The observed zenith intensity of the Cameron bands is 16.7 kR and is in good agreement with a theory with electron-impact dissociation as the most important excitation mechanism. The observations suggest the value of the cross section for this process should be 7×10^{-17} cm^2.
J. Geophys. Res., Blue, Paper 1A0016

6510 Atmospheres of planets
ION TEMPERATURE ANISOTROPY AND HEAT FLOW IN THE VENUS LOWER IONOSPHERE
R.W. Schunk (Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah 84322) and J.-P. St.-Maurice

Motivated by the recent observations of supersonic ion flow in the Venus ionosphere near the terminator, we have studied the extent to which such a flow can induce an ion temperature anisotropy and a diffusion-thermal heat flow. Our calculations indicate that appreciable ion temperature anisotropies can be induced at altitudes below about 210 km. The temperature anisotropy is with respect to the ion-neutral relative drift velocity vector, with the ion temperature parallel to the relative drift velocity greater than the perpendicular ion temperature. The parallel to perpendicular ion temperature ratio is likely to be in the range of from 1-5, depending on the ionospheric …

Particles and Fields—Interplanetary Space

Particles and Fields—Ionosphere

Particles and Fields—Magnetosphere

5705 Bow shock waves
A STATISTICAL SURVEY OF IONS OBSERVED UPSTREAM OF THE EARTH'S BOW SHOCK: ENERGY SPECTRA, COMPOSITION, AND SPATIAL VARIATION
F. M. Ipavich (Dept. of Physics and Astronomy, University of Maryland, College Park, MD 20742) A. B. Galvin, G. Gloeckler, M. Scholer and D. Hovestadt

The characteristics of 33 diffuse particle events in the energy range from ~30 to ~130 keV/Q observed upstream of the earth's bow shock have been determined. The measurements were made with the Ultra Low Energy Charge Analyzer (ULECA) sensor of the Max-Planck Institut/University of Maryland instrument on ISEE-1. The energy spectra of these events are clearly steeper than power law and are generally well described by either an exponential or Maxwellian in energy per charge, with average e-folding values of ~20 keV/Q and ~15 keV/Q, respectively. The composition in these events is remarkably constant as a function of energy per charge and is similar (within a factor of ~2) to that of the solar wind. The particle flux is found to decay exponentially with distance from the bow shock, with an e-folding distance of ~7 R_E for H and He at 30 keV/Q. Inverse velocity dispersion was observed in each event, with an average delay time of ~40 min. between the 30 keV and 130 keV proton equilibrium intensity levels. Our measurements are consistent with a Fermi acceleration mechanism and the presence of a free escape boundary upstream of the bow shock. (Upstream particles, Fermi acceleration, composition.)
J. Geophys. Res., Blue, Paper 0A1914

5705 Bow shock waves
MEASUREMENTS OF BOW SHOCK PARTICLES FAR UPSTREAM FROM THE EARTH
K. A. Anderson (Physics Department and Space Sciences Laboratory, University of California, Berkeley, CA 94720)

Electrons and ions moving upstream frequently appear at distances up to 240 R_E from Earth at times when the direction of the interplanetary magnetic field allows their propagation from the bow shock. Strong asymmetries in the ion angular pitch angle distribution are often observed, a consequence of the sharp gradient in guiding center density and very weak scattering. The gradient is due to the restricted spatial region over which these particles are accelerated. The solar wind electric field, $E = -V_{sw} \times B_{imf}$ acts on these particles and produces striking effects in both the ion angular distributions and the ion energy spectra.
J. Geophys. Res., Blue, Paper 1A0020

5705 Bow shock waves
CORRELATED WAVE AND PARTICLE OBSERVATIONS UPSTREAM OF THE EARTH'S BOW SHOCK
C.C. Harvey (Observatoire de Paris, [illegible]

Planetology

6510 Atmospheres of Planets
SPECTROSCOPY OF THE CAMERON BANDS IN THE MARS AIRGLOW
R. R. Conway (LASP, Univ. of Co., Campus Box 392, Boulder, CO 80309)

Mars airglow spectra acquired by the ultraviolet spectrometer experiment of Mariner 9 were analyzed by using a high resolution synthesis. The carbon monoxide Cameron bands are the brightest features between 1800 and 2600 Å in the observation of altitudes between 88 and 180 km. The shape of these bands cannot be characterized by any single rotational temperature but is best described by temperatures of 1600 K for lower J values and 10,000 K for higher J values. The first negative bands of CO^+ are not identified in the residual spectra. The observed zenith intensity of the Cameron bands is 66.7 kR and is in good agreement with a theory with electron-impact dissociation as the most important excitation mechanism. The observations suggest the value of the cross section for this process should be 7 x 10^{-17} cm^2.
J. Geophys. Res., Blue, Paper 1A0016

6510 Atmospheres of planets
ION TEMPERATURE ANISOTROPY AND HEAT FLOW IN THE VENUS LOWER IONOSPHERE
R.W. Schunk (Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah 84322) and J.-P. St.-Maurice

Motivated by the recent observations of supersonic ion flow in the Venus ionosphere near the terminator, we have studied the extent to which such a flow can induce an ion temperature anisotropy and a diffusion-thermal heat flow. Our calculations indicate that appreciable ion temperature anisotropies can be induced at altitudes below about 220 km. The temperature anisotropy is with respect to the ion-neutral relative drift velocity vector, with the ion temperature parallel to the relative drift velocity greater than the perpendicular ion temperature. The parallel to perpendicular ion temperature ratio is likely to be in the range of from 1-4, depending on the ionospheric conditions. We have also found that in the same ionospheric region the ion-neutral relative drift induces a diffusion-thermal heat flow that is considerably more important than ordinary ion thermal conduction. Consequently, diffusion-thermal heat flow could have an appreciable effect on the ion energy balance in the Venus lower ionosphere.
J. Geophys. Res., Blue, Paper 1A0217

6510 Atmospheres of planets
H_2 ABUNDANCE IN THE ATMOSPHERE OF VENUS
S. Kumar, D.M. Hunten (Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721) H.A. Taylor, Jr.

The in situ measurements from the Pioneer Venus Orbiter (PVO) Ion Mass Spectrometer have led to the detection of H_2^+ ions in the Venus ionosphere. Although H_2^+ is a minor ion, its measurement provides the first direct clue for determining the H_2 abundance in the upper atmosphere of Venus. A photochemical model using PVO measurements is used to derive an H_2 mixing ratio of 10 ppm below 130 km altitude. The presence of this much H_2 confirms our previous prediction that the reactions of O^+ with H_2 and subsequent recombination of OH^+ provide an important source of nonthermal H observed in the Venus exosphere. The estimated escape flux for H is 10^8 cm^{-2} s^{-1}. (Venus, aeronomy, ionosphere)
Geophys. Res. Lett., Paper 1L0111

6510 Atmosphere of planets
AURORA IN JUPITER'S ATMOSPHERE?
A.F. Cook II, A. Vallance Jones and D.E. Shemansky (Earth and Space Sciences Institute, University of Southern California, Tucson Laboratories, Tucson, AZ 85713)

The darkside limb pictures obtained by the imaging experiment on Voyager 1 have been reexamined. It is concluded that the observed luminosity is very likely due at least in part to Io torus aurora. If the effective wavelength of the emission lies in the 4000 Å to 5000 Å region, the slant intensity is estimated to be about 20 kR. The observed double structure may be due to a number of causes such as horizontal structure in auroral emission, aurora plus twilight or photochemical airglow plus aurora. (aurora, Jupiter, imaging).
J. Geophys. Res., Blue, Paper 1A0073

6575 Surface of planets
ORIGIN OF MARTIAN OUTFLOW CHANNELS: THE EOLIAN HYPOTHESIS
J.A. Cutts (Planetary Science Institute, Science Applications, Inc., 283 S. Lake Ave., Suite 218 Pasadena, CA 91101) K.R. Blasius

The ancient outflow channels on Mars exhibit fossil flow patterns similar to current flow patterns in terrestrial desert regions eroded by wind. We have modelled outflow channel formation by a cascade process in which sand-sized particles produced by rock weathering in the chaotic terrain "source areas" of the outflow channels were transported by the wind across the adjacent plateau surfaces sand blasting and deflating the surface. Comparisons of model predictions with photogeologic data suggest that rates of rock breakdown by physical and chemical action along the channels during the channel forming era must have been much higher than they have been on similar terrains formed after the channel era ended. A tenuous atmosphere, comparable to the present one, would have transported materials sufficiently rapidly to excavate outflow channels in about 10^6 years. However, there may be difficulties in explaining how abrading particles could survive high velocity impacts in a thin atmosphere over the many hundreds or even thousands of kilometers that they were transported in outflow channels. It is difficult to avoid the conclusion that a climate change affecting rock breakdown rates, atmospheric density, or both occurred early in martian history to end the era of outflow channel formation. Particulate materials generated during this era may be important components of the north circumpolar dune field and the polar layered deposits. (Mars, channels, erosion, climate, wind).
J. Geophys. Res., Red, Paper 1B0021

6575 Surface of Planets
COORDINATES OF FEATURES ON THE GALILEAN SATELLITES
M. E. Davies (The Rand Corporation, Santa Monica, California 90406) and F. Y. Katayama

Control nets of the four Galilean satellites have been established photogrammetrically from pictures taken by the two Voyager spacecraft during their flybys of Jupiter in 1979. Coordinates of 504 points on Io, 112 points on Europa, 1547 points on Ganymede, and 439 points on Callisto are listed. Selected points are identified on USGS maps of the satellites. Measurements of these points were made on 134 pictures of Io, 115 pictures of Europa, 281 pictures of Ganymede, and 200 pictures of Callisto. The systems of longitude were defined by craters on Europa, Ganymede, and Callisto. Preliminary solutions have been found for the directions of the axes of rotation of the Galilean satellites. New mean radii have been determined as 1815 ± 5 km for Io, 1569 ± 10 km for Europa, 2631 ± 10 km for Ganymede, and 2400 ± 10 km for Callisto. (Galilean satellites, coordinates, features).
J. Geophys. Res., Red, Paper 80A1118